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William Ernest Cross

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ON

METHODS OF ANALYSIS

OF

CANE PRODUCTS

BY

WM. E. CROSS.

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PREFACE.

The following bulletin consists of a report of investigations on the methods of analysis of sugar cane products carried out in the Chemical Department of the Experiment Station during the past fifteen months.

It is universally recognized that accurate chemical control of a sugar factory and dependable analysis of the products turned out are essential to scientific progress in sugar manufacture, and it is therefore a matter of vital importance to have the methods of determination of such products of the highest accuracy and the greatest practicability. In the following pages are submitted reports of experimental efforts in the direction of elaborating and perfecting such methods, as well as investigations on the analysis of sugar products in general.

It is hoped that the work here reported will be of value to the sugar chemists of the State, and I trust that this bulletin may claim their serious consideration.

My thanks are due to Mr. W. G. Taggart, Assistant Chemist, to whose loyal, painstaking, and competent assistance much of the success of the work here reported is due.

WM. E. CROSS, Chemist.

Audubon Park, New Orleans, La., April 26, 1912.

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CHAPTER I.

The Determination of Dry Substance; the use of the Refractometer in Sugar House Work.

The question of the determination of dry substance in sugar-house products has occupied the attention of chemists for many years. The methods most favored have been mainly densimetric in character; assuming that the non-sugars in solution had about the same specific gravity as sucrose, the density was measured by the picnometer, spindle, or other method, and the concentration of the solution obtained by assuming the solution to be one of pure sucrose. The results thus obtained with impure solutions (e. g. molasses) were far from being correct, owing to the widely varying specific gravities of the solutions of the different non-sugars. It was therefore necessary to use drying methods on such impure solutions, but here again serious difficulties were encountered. Drying of molasses, for example, in an open dish, gave different results depending on the size of the dish, etc., as the top layer would dry and form a protective shield to the rest of the solution. This difficulty was overcome by drying on sand, pumice stone, paper, etc., by which a greatly increased amount of drying surface was obtained. Even with this method, however, the results were not uniform, as the drying mass often contained substances, e. g. levulose, certain lime salts, etc., which were unstable at the temperature of the steam bath, and which consequently decomposed, producing gaseous substances, and an exaggerated loss in weight and apparent water content. Heating at a lower temperature in vacuum reduced the possibility of error (though it did not entirely eliminate it) and we thus have the vacuum method, using sand, etc., as the best drying method available. This is the official method in Germany, Russia, and several other countries.

The vacuum method is, however, somewhat awkward for routine work, and efforts have been made to replace this by drying at 100° C. in the ordinary steam bath. Much work carried out by the referees and collaborators of the Association of Official

Agricultural Chemists in this country (1) has shown that heating for ten hours in a steam oven gives results which are practically identical with those of the drying method for most molasses.

One of the first suggestions as to the use of the refractometric principle, and especially the Abbé refractometer, for the determination of dry substance in syrups, etc., is due to Hugh Main, (2) who worked out a table of refractive indices of sugar solutions of all concentrations at 20° C. Earlier work had included that of Stolle, (3) who obtained values for the refractive indices of sugar solutions of different concentrations, using the immersion refractometer, and of Tolman and Smith, (4) who repeated and confirmed Stolle's work, using the Abbé instrument, including also glucose in the scope of their investigations, and showing that glucose and sucrose in solution have the same refractometric index at all concentrations.

The work of these and other investigators showed conclusively the absolute reliability of the refractometer for determining the percentage of sugar in pure solution. The accuracy of the method for determining dry substance in juices, syrups, etc., was still in question, as the extent to which the refractive indices of the non-sugars differed from that of sucrose had not been investigated.

Tolman and Smith showed that sucrose, fructose and glucose all have the same indices of refraction in solutions of concentration 0%-90%, but the investigation of the other substances found in sugar products was left to Prinsen-Geerligs. This investigator, working with the Abbé instrument, first confirmed the observations of Tolman and Smith regarding the specific refraction of reducing sugars, and then obtained refractive data on such inorganic substances, e. g. chlorides, sulphates, acetates, etc., as are commony found in cane products. The work showed that the calcium salts had a higher, the potassium salts a lower index of refraction than sucrose, and Geerligs proved by experiment that a mixture of these salts such as is usually found in sugar products gave results very nearly the same as those of

(1) Bulletins Bureau of Chemistry, U. S. Dept. Agric.
(2) I. S. J., Vol. 9, 481.
(3) Zeit. ver. Zuckerind. 1901. 469.
(4) Jour. Am. Chem. Soc. Oct., 1906.

pure sucrose. Artificial mixtures of syrups with salts such as are found in molasses were made up and tested, and the refractometric results agreed very well with the known calculated values. Calcium and potassium glucinates, commonly occuring products of the action of alkalies on juices, also had refractive indices approximating very closely to that of sucrose. Geerligs concluded by recommending the refractometric method both on grounds of theoretical soundness and as a practically valuable and convenient method for sugar-house work. He also prepared a table of refractive indices of sugar solutions, with 28° C. as his standard temperature. The practical sugar-house aspect of the method was further discussed by Geerligs and Went (5), and here also Geerligs recommended the Abbé refractometer for determining dry substance in molasses, syrups, etc.

Since Geerligs' important publication appeared, much work has been done on various aspects of the question, among which may be cited Wiechmann's Refractometric Studies (6), Pellet's (7) investigations, in which he agrees with Geerligs in recommending the use of the Abbé instrument, and Nowakowski and Muszynski (8), who recommend the Abbe instrument for juices, syrups and molasses, as giving results which are better than those of the picnometric method, and which indeed approximate very closely to those of the drying method.

Other work which may be mentioned is that of Tischtschenko (9). This investigator explained the observation (which had been noticed by several workers) that the results on dry substance obtained when a molasses was diluted with its own weight of water were too high. He accounted for this by the fact that contraction takes place on dilution, and suggested that if a fairly concentrated solution of pure sucrose were used instead of water for diluting, the contraction would be greatly minimized while the desired clearness of field would still be secured. This innovation has been found to work well in practice and the method is very useful in ensuring approximately correct results on dark molasses, etc.

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(5) Mededeel van het. Proefstation voor Suikerriet in West Java, 99.
(6) I. S. J. 1908, Nov.
(7) Bull. Assoc Chem. Dist. Sucr., *26*, 337.
(8) Wentnik. Sacch. Prof., *9*, 272.
(9) Zeitschrift. ver. Zuckerind., *59*, 103.

The Abbé and the Immersion refractometers are the most useful for sugar work, although several others are known, e. g., the "interference" refractometer, the new "Universal" refractometer of Lewkowitsch (10), etc. The Abbé refractometer, which is the most popular, is designed to give the refractive index of sugar solutions of any concentration. The scale of the instrument is graduated from refractive index 1.3000 to 1.7000, the scale being graduated to the third place of decimals, the fourth being estimated by the eye. A valuable improvement would be a vernier attachment by which the fourth place could be read with greater accuracy than with the present arrangement. A maximum error of .0001 in the refractive index may, however, be obtained with most sugar-house products with careful work. This corresponds to an error of $\pm$ .1% dry substance with low concentrations and $\pm$ .05% with higher concentrations.

The great convenience of the Abbé instrument is the fact that the refractive index of sugar solutions of any concentration may be read off directly—without previous dilution. An experienced operator can thus obtain the dry substance even of a low-grade molasses in a few moments. A very dark sample may sometimes be bleached satisfactorily with an infinitesimal quantity of bleaching agent and thus the moisture content directly obtained.

The *Immersion* refractometer is more limited in its application, as it can only be used for concentrations up to 22%. It aims at greater accuracy, however, as its smaller scale divisions correspond approximately to .0004 (refractive index) and the reading of intermediate values is assisted by a micrometer scale arrangement which reduces the error in reading to the neighborhood of $\pm$ .00004. It is thus the ideal instrument for accurate work in solutions of low concentration.

With both instruments very close attention must be given to keeping the temperature constant, as the error introduced by even one degree C. is comparatively great. With the immersion refractometer a bath is provided, the temperature of which can be kept constant without much difficulty, but great care must be taken that the solution in the tiny beaker, which is immersed

(10) J. Soc. Chem. Ind., 28, 773.

in the bath, attains the same temperature as the bath before the reading is made. The Abbé instrument is fitted with an arrangement in which the water from a constant temperature bath can be made to flow around the prisms. For any accurate work the prisms should be kept at a constant temperature in this manner.

As to the application of these instruments, we have found the one better for some determinations, and the other for others. In a laboratory which possesses both the Abbé and the Immersion instruments, if these are carefully standardized to the test plate and to each other, either instrument may be used—sometimes one, sometimes the other—depending on the concentration of the solution, etc. and thus entirely uniform results can be obtained on all sugar-house products, with the complete elimination of the inaccurate spindle method. For juices, the immersion instrument would be best, the dry substance being thus obtained to within $\pm$ .04%, although many juices are difficult to read with this instrument, in which case the Abbé instrument should be used, the error here being about $\pm$ .1%. Clarified juices can of course always be read by the immersion instrument.

It may be said that, if the accuracy of the refractometer for juices is no greater than with the Brix spindle, there should be no advantage in using the former instrument in this determination. It is easily seen, however, that apart from the greater simplicity and reliability of working ensured by the refractometer, the refractometric results on juices are the only ones logically comparable to the refractometric dry substance results on syrups, molasses and massecuites.

For syrups and molasses the Abbé instrument is very satisfactory. A sample is placed between the prisms, and the refractive index read off, careful correction being made for temperature. From the tables the per cent dry substance is obtained directly. Except with very dark low-grade samples, diluting is not necessary. A great amount of work has been done on this determination, and results have shown that the method yields values which very closely approximate to those of the official drying method. If the molasses is too dark to read, and the use

of a grain of Blankit does not help matters, the sample should be dissolved in its own weight of fairly concentrated sugar solution. This is theoretically sounder than simple aqueous dilution (12), and the results actually obtained approximate more nearly to those in the undiluted sample (13).

We have been able to make a very thorough test of the refractometric method for molasses, etc., by working in co-operation with the Association of Official Agricultural Chemists in our work as referee on sugars. In this way the assistance of many collaborators was obtained in our study of these problems.

The following table gives some results obtained in 1911 by different observers: (14.)

TABLE I.

(COMPARATIVE RESULTS ON THE DETERMINATION OF MOISTURE IN MOLASSES.)

Observer	Heating 10 hours at 100° with sand	Heating 10 hours at 100° without sand	Vacuum at 70°	Hours	Vacuum at 70° 50 g. sand	Hours	Brix	Refractometer		
								Undiluted	Dil. water	Dil. sugar solution
A	21.37	21.26	21.10	25	22.3	26	16.76	20.25	19.04	18.10
B	20.42	20.45	.....	....	.....	....	17.20	20.73	19.24	20.23
C	21.96	21.25	20.15	26	20.70	26	16.50	20.35	19.72	20.64
D	22.15	20.81	19.43	....	.....	....	18.36	.....	.....	.....
E	21.21	20.32	.....	....	.....	....	17.24	20.50	.....	.....
F	21.55	20.18	.....	....	.....	....	.....	.....	.....	.....
G	21.96	21.40	20.80	20	20.70	20	17.80	20.70	20.10	21.00
H	20.90	.....	.....	....	.....	....	18.50	20.60	20.10	20.87
I	.....	.....	.....	....	.....	....	.....	21.10	20.37	20.70
Average .	21.44	20.81	20.37		21.12		17.48	20.60	19.76	20.25

These results are given as typical of many others obtained by us, and by other workers, which show that for syrups, molasses, etc., the refractometric method, including Tischtschenko's dilution modification, is entirely reliable.

(12) Tischtschenko. loc. cit.

(13) If C = total solids of mixture, and D = total solids of sugar solution, then total solids of molasses sample = 2C—D. This formula applies only when the molasses is diluted with its own weight of sugar solution. Otherwise, let A = wt. of sample, B = wt. of sugar solution, C and D as above, then total solids of molasses = $\frac{(A + B)\ C - DB}{A}$

(14) Cf. Bull. 152, Bureau of Chemistry, Washington, p. 102.

Where the whole of the sugar is in solution, no matter what the concentration, the dry substance can usually be read off directly by the Abbé refractometer. In some houses this instrument has, therefore, given very useful service in controlling the boiling of molasses, etc., to string proof. A sample is taken from the proof-stick at frequent intervals and the dry substance immediately determined by the Abbé refractometer. In this way the boiling can be carefully controlled, and the pan struck exactly when the desired density is reached. The possibility of easily and accurately controlling the boiling of low-grade products to string proof, thus furnished by the Abbé refractometer, is of considerable importance and value.

When the molasses, etc., contains crystals, complete solution must be assured by the addition of more water. If a massecuite is dissolved in its own weight of water, and care be taken to prevent evaporation, the total water content of the solution can be obtained by the Abbé instrument, and thus the water content of the original sugar or massecuite deduced. Carefully conducted, we have found this method to yield good results in much less time than the usual drying method.

The refractometer offers a fairly accurate method for the determination of moisture in sugars. With the Abbé refractometer, the method we have found most practical consists of weighing out 20 gms. of the sugar in a tared flask, and dissolving this in 20 gms. of water. The flask is then carefully stoppered, and the mixture shaken till the whole of the sugar is dissolved. The refractive index, and therefore the dry substance of the solution is then determined, and the water content of the sugar calculated. For example, with one sugar, 20 gms. sugar and 20 gms. water, gave:

Refractometric reading = 1.4199. (t = 24° C.)
Corrected = 1.4167.— (28° C.)

which corresponds to 49.05% dry substance.

But we had 50.00% sugar in solution.

50 gms. sugar contain .95 gms. moisture.

% moisture in sugar, 1.9%.

If 20 gms. sugar and not exactly 20 gms. water are used (and weighing thus is more convenient), the following formula may facilitate calculation:

$$\% \text{ Moisture in sugar} = \frac{2000 - XY}{20}$$

Y = % total solids of solution
X = Wt. of sugar and water (gms.)

e g., 20 gms. sugar dissolved in 20.6 gms. water.

Total solids of solution (by refractomer) = 48.3%.

Then X = 40.6 Y = 48.3%

$$\% \text{ Moisture in sugar} = \frac{2000 - XY}{20}$$

$$= \frac{2000 - 1961}{20} = 1.95\%.$$

If the sugar is not weighed out to exactly 20 gms., letting weight be "Z," we have

$$\% \text{ Moisture} = \frac{100 - XY}{Z}$$

This method with the Abbé refractometer works excellently in practice and is reasonably accurate. Assuming the error in reading the refractometer to be about = $\pm$ .0001, we have an error of about $\pm$ .05= as the total of solids of the solution, which should correspond to $\pm$ .1% moisture in the sugar.

The application of the Immersion Refractometer to this determination is best carried out by the method suggested by Stolle (11): 20 gms. of the sugar are taken and dissolved in a 100 cc. flask, the solution being carefully made up to the mark. The refractive value is then read off by means of the Immersion refractometer, and by reference to tables the moisture content is obtained.

In our experiments with various methods we have found this to be the best for this instrument. No difficulty is experienced in

(11) I. S. J., *13*, 90.

obtaining a clear field with most sugars, but when the solutions are very dark, so that reading is difficult, good results can almost always be obtained by raising the small containing beaker so that the end of the refractometer almost touches the bottom. In this way the thickness of the layer through which the light has to pass is reduced and easier reading assured.

TABLE II.

WATER CONTENT OF RAW SUGAR.

20 grms. in 100 c.c. at 17.5° C.

Refractometer Degrees	Percentage of Water	Refractometer Degrees	Percentage of Water	Refractometer Degrees	Percentage of Water	Refractometer Degrees	Percentage of Water
88.0	4.900	89.0	3.650	90.0	2.400	91.0	1.150
88.1	4.775	89.1	3.525	90.1	2.275	91.1	1.025
88.2	4.650	89.2	3.400	90.2	2.150	91.2	0.900
88.3	4.525	89.3	3.275	90.3	2.025	91.3	0.775
88.4	4.400	89.4	3.150	90.4	1,900	91.4	0.650
88.5	4.275	89.5	3.025	90.5	1.775	91.5	0.525
88.6	4.150	89.6	2.900	90.6	1.650	91.6	0.400
88.7	4.025	89.7	2.775	90.7	1.525	91.7	0.275
88.8	3.900	89.8	2.650	90.8	1.400	91.8	0.150
88.9	3.775	89.9	2.525	90.9	1.275	91.9	0.025

Corrections for hundredths of a scale-division:

0.03 scale division = — 0.04 per cent. Water.
0.05 scale division = — 0.06 per cent. Water.
0.07 scale division = — 0.09 per cent. Water.

A factor of the greatest importance in this determination is the temperature. As will be seen from Table III, very small variations in temperature produce large changes in the result obtained for the water content of sugar. An error of half a degree in the temperature reading can produce an error of .2% in the value obtained for water content. Everything possible must therefore be done to ensure a constant temperature being maintained. The bath should be filled with water of a suitable temperature, and we have found it best to allow the flask containing the solution to stand for some time in the bath, so that the solution attains the temperature of the bath before being poured into

the small beakers. The reading should be carried out expeditiously as soon as the liquid is poured into the beakers, as slight evaporation may affect the results seriously.

TABLE III.

TEMPERATURE CORRECTION TABLE FOR THE REFRACTOMETRIC DETERMINATION OF WATER IN RAW SUGAR.

Degrees Centigrade	To be Subtracted*	Degrees Centigrade	To be Added*	Degrees Centigrade	To be Added*	Degrees Centigrade	To be Added*
15.0	0.72	17.6	0.03	20.2	0.82	22.8	1.62
15.1	0.70	17.7	0.06	20.3	0.85	22.9	1.65
15.2	0.67	17.8	0.09	20.4	0.88	23.0	1.69
15.3	0.64	17.9	0.12	20.5	0.91	23.1	1.72
15.4	0.61	18.0	0.15	20.6	0.94	23.2	1.75
15.5	0.58	18.1	0.18	20.7	0.97	23.3	1.78
15.6	0.55	18.2	0.21	20.8	1.00	23.4	1.81
15.7	0.52	18.3	0.24	20.9	1.03	23.5	1.85
15.8	0.49	18.4	0.27	21.0	1.06	23.6	1.88
15.9	0.46	18.5	0.30	21.1	1.09	23.7	1.91
16.0	0.44	18.6	0.33	21.2	1.12	23.8	1.96
16.1	0.41	18.7	0.36	21.3	1.15	23.9	1.99
16.2	0.38	18.8	0.39	21.4	1.18	24.0	2.03
16.3	0.35	18.9	0.42	21.5	1.22	24.1	2.06
16.4	0.32	19.0	0.45	21.6	1.25	24.2	2.09
16.5	0.29	19.1	0.48	21.7	1.28	24.3	2.12
16.6	0.26	19.2	0.51	21.8	1.31	24.4	2.15
16.7	0.23	19.3	0.54	21.9	1.34	24.5	2.19
16.8	0.20	19.4	0.57	22.0	1.37	24.6	2.22
16.9	0.17	19.5	0.61	22.1	1.41	24.7	2.25
17.0	0.15	19.6	0.64	22.2	1.44	24.8	2.29
17.1	0.12	19.7	0.67	22.3	1.47	24.9	2.32
17.2	0.09	19.8	0.70	22.4	1.50	25.0	2.35
17.3	0.06	19.9	0.73	22.5	1.53	25.1	2.38
17.4	0.03	20.0	0.76	22.6	1.56	25.2	2.42
17.5	0.00	20.1	0.79	22.7	1.59	25.3	2.45

*From or to refractometer reading.

If careful attention be given to the points here emphasized, excellent results can be obtained with this method.

In Table IV will be found values obtained in a number of experiments on various kinds of sugars, by the official drying, as well as by the two refractometric methods here given. The author believes the method with the Abbé instrument to be the more accurate for this determination, as the dilution, and the

consequent multiplication of the error, is smaller. The method with the immersion refractometer, however, is somewhat simpler and more convenient.

TABLE IV.

PERCENTAGE MOISTURE IN SUGAR BY VARIOUS METHODS.

	SAMPLES	Drying	Abbe	Immersion
	By WM. E. CROSS.			
1.	Firsts	.97	1.00	1.15
2.	Seconds	3.38	3.10	3.24
3.	Y. C.	2.39	2.70	2.40
4.	Firsts	1.03	.....	1.15
5.	Y. C.	1.40	1.30	1.50
6.	Firsts	1.20	1.20	1.27
7.	Y. C.	.70	.65	.72
8.	Firsts	1.95	2.10	2.02
9.	Seconds	1.30	1.22	1.15
10.	Peruvian	.44	.34	.40
11.	Firsts	2.12	1.90	1.90
12.	Seconds	2.70	2.60	2.90
13.	Firsts	1.65	1.70	1.60
	By W. G. TAGGART.			
14.	96° Test	2.33	2.32	2.40
15.	96° Test	3.12	3.04	3.38
16.	Y. C.	1.12	1.14	1.34
17.	Seconds	1.51	1.42	1.15
18.	96° Test	1.34	1.30	1.26
19.	96° Test	.90	.90	.91
20.	96° Test	1.30	1.50	1.34
21.	Seconds	3.32	3.30	3.11

It should be added that only approximate results are obtainable with low grade third sugars, owing to the difficulty of reading the solutions obtained with the refractometer, and owing also to the quantity of insoluble impurities in the samples.

For the standardization of Brix spindles, the Immersion refractometer, with its low maximum error, is better adapted than the Abbé instrument, though either may be usefully employed for this purpose. The method consists simply in preparing a solution of granulated sugar, bringing it to the temperature for which the instrument was graduated, and determining the dry substance by means of the spindles to be tested. The values then obtained are checked by means of the values obtained by

means of the refractometer. The following table gives some results obtained in this work, with three different solutions.

TABLE V

Abbe Refractometer	Immersion Refractometer	BRIX SPINDLES A	B	C	D	E	F	G
16.92	16.89	16.93	16.80	16.91	16.90	16.95	17.00	16.91
11.00	11.03	11.05	10.95	11.00	11.02	11.04	11.09	11.00
19.00	19.00	19.02	18.90	19.02	19.01	19.05	19.12	19.04
Ave. 15.64	15.64	15.66	15.55	15.64	15.64	15.68	15.74	15.65

From these results one would judge spindle B to read almost .1 too low and spindle F about .1 too high. Spindle E reads a little too high, but the .04% excess is possibly within the experimental error.

To conclude, the refractometric method is one of great value and reliability in determining the dry substance of all sugar-house products: juices, syrups, molasses, massecuites and sugars. For some determinations the Abbé refractometer is specially adapted, while for others the immersion instrument is most suitable, but if the instruments are standardized with each other they can be used in conjunction for sugar house control.

The refractometric method ensures higher accuracy as well as a greater simplicity of working than the older methods, so that it appears probable that the refractometer may soon be regarded as an instrument as indispensable to sugar-house work as the polariscope has grown to be.

In the appendix are tables showing the relation between refractive index and total solids (Brix value) for use both with the Immersion and the Abbé refractometer.

CHAPTER II.

The Application of Dry Lead Defecation to Sugar House Analysis.

The ordinary method of clarifying sugar solutions for analysis, by adding lead subacetate solution and then filling up to the 100 cc. mark with water, involves a slight error in the fact that the volume occupied by the lead precipitate reduces the true volume of the solution. In this way too high polarization results are obtained. Among methods suggested to obviate this error, is the defecation with dry lead subacetate, first proposed by W. D. Horne (1). In this method the sugar solution is made up to the 100 cc. mark before the addition of the dry powdered lead subacetate, so that the proper concentration of the solution is assured. The method was subjected to considerable criticism at first, however, especially from Pellet (2), who stated that owing to occlusion of sugar by the lead precipitate, which thus attained a concentration of sucrose approximately the same as that of the solution, the concentration of the solution was the same as if no lead precipitate were present. After a long controversy, it was shown conclusively by Horne (3) that the lead precipitate does not entrain sugar, and thus also that the supposed error due to the volume occupied by the lead precipitate is a real one.

The question was also brought up as to the diluting effect of the dry lead subacetate which is added after the solution has been made up to the 100 cc. mark, and so increases the volume in a degree dependent upon the amount of salt going into the solution. It has been experimentally shown, however, that the amount of lead remaining in solution with ordinary work is very small, and that the increase in volume due to this is so small as to be entirely insignificant.

It would appear therefore that the theoretical superiority of the dry lead method has been well established.

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(1) J. Am. Chem. Soc. 1904. 186.
(2) Bull. Assoc. Chem. Dist. 1905. 285-291. I. S. J. 1906. 17.
(3) J. Am. Chem. Soc. 1907. 926.

In its application to the control work of a cane sugar house, we have found it a method of greater simplicity than the older methods, and this in itself is a great advantage. Moreover, its accuracy for the various products has been tested by us at the Experiment Station with very favorable results.

For example, with juices. Here the dry lead method consists of pouring a convenient quantity of juice into a beaker, adding the quantity of dry lead requisite for clarification, stirring, filtering, and polarizing. The necessity of volumetric measurement, as in the Schmitz and Spencer-pipette methods, is thus avoided, and so both rapidity and accuracy are assured.*

In our experiments the Schmitz and dry lead methods were compared on many kinds of juices, and by different observers. The following table contains some typical results:

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*The direct polarization values obtained on juices by the dry lead method may be converted into % sucrose by reference to TableII. This table corresponds to the Schmitz table used with the Schmitz method.

Table I.

SUCROSE IN CANE JUICES.*

Description	By Schmitz Method	By Horne's Method
By Wm. E. Cross.		
Normal Juice	13.77	13.71
Normal Juice	12.80	12.86
Normal Juice	13.00	13.00
Normal Juice	13.40	13.35
First Mill Juice	15.15	15.20
First Mill Juice	14.40	14.30
Last Mill Juice	6.50	6.40
Clarified Juice (Carbonation)	11.75	11.76
Clarified Juice (Carbonation)	11.80	11.78
Clarified Juice (Sulphitation)	12.05	12.06
Clarified Juice (Sulphitation)	14.39	14.42
Average	12.64	12.62
By W. G. Taggart.		
Normal Juice	11.62	11.64
Normal Juice	13.93	13.70
Normal Juice	13.92	13.93
Normal Juice	10.61	10.60
Clarified Juice (Carbonation)	12.15	12.13
Clarified Juice (Carbonation)	8.08	7.99
Clarified Juice (Carbonation)	12.80	12.72
Clarified Juice (Sulphitation)	11.05	11.03
Clarified Juice (Sulphitation)	11.98	11.98
Average	11.79	11.75
By A. P. Kerr.		
Normal Juice	11.30	11.30
Sulphured Juice	10.80	10.80
Clarified Juice	11.30	11.30
Normal Juice	10.10	10.20
Sulphured Juice	9.50	9.50
Clarified Juice	9.90	9.80
Normal Juice	11.40	11.50
Sulphured Juice	11.30	11.30
Clarified Juice	10.80	10.80
Average	10.71	10.72
Syrup	46.80	46.60
Syrup	48.00	48.00
Syrup	42.00	41.90
Average	45.60	45.50

*Single Polarization.

These results go to show that practically identical results may be expected from both methods, and the fact that the simplicity

of the operation involved in the dry lead method minimizes the possibility of experimental error, and allows of much quicker operation in routine work, will commend the method to the sugar-house chemist.

TABLE II.

SUCROSE BY HORNE'S DRY LEAD METHOD.

Brix Reading (Uncorrected).

Polariscope reading	9	10	11	12	13	14	15	16	17	18	Polariscope reading
25	6.27	6.25	6.22	6.70	6.17	6.15	6.12	6.10	....	....	25
26	6.52	6.50	6.47	6.44	6.42	6.39	6.37	6.34	....	....	26
27	6.77	6.75	6.72	6.69	6.66	6.64	6.61	6.58	....	....	27
28	7.02	7.00	6.97	6.94	6.91	6.88	6.86	6.83	....	....	28
29	7.27	7.25	7.22	7.19	7.16	7.13	7.10	7.07	....	....	29
30	7.53	7.50	7.47	7.44	7.41	7.38	7.35	7.32	....	....	30
31	7.78	7.75	7.71	7.68	7.65	7.62	7.59	7.56	....	....	31
32	8.03	8.00	7.96	7.93	7.90	7.87	7.84	7.80	....	....	32
33	8.28	8.25	8.21	8.18	8.15	8.12	8.08	8.05	....	....	33
34	8.53	8.50	8.46	8.43	8.40	8.36	8.33	8.29	....	....	34
35	8.78	8.75	8.71	8.68	8.64	8.61	8.57	8.54	....	....	35
36	.....	9.00	8.96	8.92	8.89	8.85	8.82	8.78	8.75	....	36
37	.....	9.25	9.21	9.17	9.14	9.10	9.06	9.03	8.99	....	37
38	.....	9.50	9.46	9.42	9.38	9.35	9.31	9.27	9.23	....	38
39	.....	.....	9.71	9.67	9.63	9.59	9.55	9.51	9.48	....	39
40	.....	.....	9.96	9.92	9.88	9.84	9.80	9.76	9.72	....	40
41	.....	.....	10.21	10.17	10.12	10.08	10.04	10.00	9.96	....	41
42	.....	.....	10.46	10.41	10.37	10.33	10.29	10.25	10.21	....	42
43	.....	.....	....	10.66	10.62	10.58	10.53	10.49	10.45	....	43
44	.....	.....	....	10.91	10.87	10.82	10.78	10.74	10.69	10.65	44
45	.....	.....	....	11.16	11.11	11.07	11.03	10.98	10.94	10.89	45
46	.....	.....	....	11.41	11.36	11.32	11.27	11.22	11.18	11.13	46
47	.....	.....	....	....	11.61	11.56	11.52	11.47	11.42	11.38	47
48	.....	.....	....	....	11.86	11.81	11.76	11.71	11.67	11.62	48
49	.....	.....	....	....	12.10	12.06	12.01	11.96	11.91	11.86	49
50	.....	.....	....	....	12.35	12.30	12.25	12.20	12.15	12.10	50
51	.....	.....	....	....	....	12.55	12.50	12.45	12.40	12.35	51
52	.....	.....	....	....	....	12.80	12.74	12.69	12.64	12.59	52
53	.....	.....	....	....	....	13.04	12.99	12.93	12.88	12.83	53
54	.....	.....	....	....	....	13.29	13.23	13.18	13.13	13.07	54
55	.....	.....	....	....	....	....	13.48	13.42	13.37	13.32	55
56	.....	.....	....	....	....	....	13.73	13.67	13.61	13.56	56
	†	‡									
57	0.1	0.02	....	....	....	....	13.97	13.91	13.86	13.80	57
58	0.2	0.05	....	....	....	....	14.22	14.16	14.10	14.04	58
59	0.3	0.07	....	....	....	....	....	14.40	14.34	14.29	59
60	0.4	0.10	....	....	....	....	....	14.65	14.59	14.53	60
61	0.5	0.13	....	....	....	....	....	14.89	14.83	14.77	61
62	0.6	0.15	....	....	....	....	....	15.14	15.08	15.01	62
63	0.7	0.17	....	....	....	....	....	15.38	15.32	15.26	63
64	0.8	0.19	....	....	....	....	....	....	15.56	15.50	64
65	0.9	0.22	....	....	....	....	....	....	15.81	15.74	65

† (Tenths of a division.)

‡ (% Sucrose.)

The dry lead defecation may also be used in the analysis of syrups, sugars and molasses. Very considerable work has been done on this subject and all the results obtained go to show that the method is both accurate and practicable for these products. For several years past, the referees and collaborators of the Association of Official Agricultural Chemists have carried out work on this method, with the result that the method has this year been made an official one for this country. Some results obtained in 1910 and 1911, when the work was organized and carried out by this department, are herein given.

TABLE III.

POLARIZATION RESULTS USING NORMAL QUANTITY CLARIFYING AGENTS.

Observer	Lead Subacetate Solution				Horne's Dry Lead			
	Molasses		Sugar		Molasses		Sugar	
	Single	Clerget	Single	Clerget	Single	Clerget	Single	Clerget
1911*								
A.....	31.00	38.66	96.50	96.51	30.50	38.74	96.35	97.00
B.....	31.20	39.19	96.60	96.38	.....	.....	96.50	96.03
C.....	30.80	38.92	96.38	96.36	30.80	38.42	96.12	96.16
D.....	.....	.....	95.78	95.55	.....	.....	95.68	95.37
E.....	31.60	38.53	95.90	96.35	31.64	38.70	95.88	96.06
F.....	31.20	38.03	96.00	96.50	31.20	38.80	96.20	97.31
G.....	32.20	39.35	96.40	97.73	32.32	39.33	96.25	97.57
H.....	32.00	39.65	96.35	97.88	32.00	39.38	96.35	97.79
I.....	29.70	37.90	95.57	97.30	29.90	37.50	95.57	96.60
Average ..	31.21	38.78	96.16	96.73	31.19	38.69	96.09	96.65
1910*								
A.....	42.10	45.31	96.65	97.20	42.00	45.23	96.60	97.10
B.....	42.21	46.83	97.16	98.26	42.08	46.50	97.20	98.21
C.....	42.60	46.12	96.40	98.78	42.40	45.96	96.35	98.78
D.....	42.00	47.52	96.00	97.98	42.40	47.83	96.10	98.23
E.....	42.10	45.66	96.35	.....	.....	.....	.....	.....
F.....	42.20	45.68	96.50	.....	43.10	.....	.....	.....
G.....	.....	.....	96.50	.....	.....	.....	96.20	.....
Average ..	42.21	46.18	96.50	98.05	42.39	46.38	96.49	98.08

*Cf. Bulletins of Bureau of Chemistry, Dept. of Agriculture.

From this table it is seen that the dry lead method gives results closely approximating to those of the old official method.

The dry lead results are theoretically the more correct, but the differences are so small as to be of only very slight importance in sugar house work. The dry lead defecation would thus appear to be very advantageous, being at the same time more easy of manipulation, and theoretically more correct than the older methods.

We have also found, as might be expected from the foregoing results on juices, molasses, etc., that the dry lead defecation may be used in filter-press cake and bagasse analysis, with reliable results.

In conclusion, it may be remarked that in ordinary work the use of excessive amounts of clarifying agent, be it dry lead or lead subacetate solution, is very undesirable (4), as in this way variations in the polarization values are obtained which seriously detract from the value of an analysis. Care should be taken, therefore, to add only just sufficient of the clarifying agent to produce the desired precipitation of impurities, etc.

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(4) Cf. however Ch. IV, this Bulletin.

CHAPTER III.

A Rapid Method for the Determination of Glucose in Juices.

In the volumetric determination of glucose in juices much time can be saved if the juice be measured out instead of weighed, and if the operation is performed carefully, with properly standardized pipettes, etc., a very good accuracy is attainable. The procedure is exactly the same as with the ordinary method, except that so many ccs., instead of so many grams, of the juice are taken and made up to 200 cc. The result is calculated exactly as if so many grams instead of ccs. had been used, and the percentage glucose obtained by Table I.

TABLE I.

TABLE FOR GLUCOSE DETERMINATION.

% Glucose	Brix (Uncorrected)										
Found	10	11	12	13	14	15	16	17	18	19	20
0.5											
0.6	.48	.48	.47	.47	.47	.47	.47	.47	.47	.46	.46
0.7	.58	.57	.57	.57	.57	.56	.56	.56	.56	.56	.55
0.8	.67	.67	.67	.66	.66	.66	.66	.65	.65	.65	.65
0.9	.77	.77	.76	.76	.76	.75	.75	.75	.74	.74	.74
1.0	.86	.86	.86	.85	.85	.85	.85	.84	.84	.83	.83
1.1	.96	.96	.95	.95	.95	.94	.94	.93	.93	.93	.92
1.2	1.06	1.05	1.05	1.04	1.04	1.03	1.03	1.03	1.02	1.02	1.01
1.3	1.15	1.15	1.14	1.14	1.13	1.13	1.13	1.12	1.12	1.11	1.11
1.4	1.24	1.24	1.24	1.23	1.23	1.22	1.22	1.21	1.21	1.20	1.20
1.5	1.34	1.33	1.33	1.33	1.32	1.32	1.31	1.31	1.30	1.30	1.29
1.6	1.44	1.44	1.43	1.42	1.42	1.41	1.41	1.40	1.40	1.39	1.38
1.7	1.54	1.53	1.52	1.52	1.51	1.50	1.50	1.50	1.49	1.49	1.48
1.8	1.63	1.63	1.62	1.61	1.61	1.60	1.60	1.59	1.58	1.58	1.57
1.9	1.72	1.72	1.72	1.71	1.70	1.69	1.69	1.68	1.68	1.67	1.66
2.0	1.82	1.82	1.81	1.80	1.80	1.79	1.79	1.78	1.77	1.76	1.75
2.1	1.92	1.91	1.91	1.90	1.89	1.88	1.88	1.87	1.86	1.86	1.85
2.2	2.02	2.01	2.00	1.99	1.99	1.97	1.97	1.96	1.96	1.95	1.95
2.3	2.11	2.10	2.10	2.09	2.08	2.07	2.07	2.05	2.05	2.04	2.03
2.4	2.21	2.20	2.19	2.18	2.17	2.16	2.16	2.14	2.14	2.13	2.12
2.5	2.30	2.30	2.29	2.28	2.27	2.26	2.25	2.24	2.23	2.22	2.22
	2.40	2.39	2.38	2.38	2.37	2.36	2.35	2.33	2.32	2.31	2.30

To take an example: 50 cc. juice are measured out by means of a pipette, into a 200 cc. flask, which is then filled up to the

mark with water. In the titration against 10 cc. Fehling's solution, 22.2 cc. of the juice solution are necessary to reduce the copper. By the ordinary calculation, this corresponds to .9% glucose. But 50 cubic centimeters, and not 50 grams, were used, so the correct value must be found from the table. Suppose the juice were 17 Brix, the glucose percentage would be 0.84.

The Spencer pipette can also be used to advantage for rapid glucose analysis. The standardized pipette is filled up to the mark corresponding to the Brix value with juice, and this volume is run into a 200 cc. flask, which is then filled up to the mark with water. This juice solution is used for the usual titration, and from the number of ccs. necessary to reduce the 10 cc. Fehling's solution the glucose percentage is obtained by reference to Table II.

For example, a juice of 15.0 Brix was taken, and a Spencer pipette filled to the 15 Brix mark with juice. This volume was run into a 250 cc. flask and the flask filled to mark with water. In the titration 18.6 ccs. were necessary, showing a glucose content (from Table II) of 1.29%.

TABLE II.

(FOR GLUCOSE DETERMINATION WITH SPENCER PIPETTE.)

1 pipette volume made up to 250 ccs.

CC. Solution required	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
12	2.00	1.99	1.96	1.95	1.94	1.92	1.90	1.89	1.88	1.86
13	1.85	1.83	1.81	1.80	1.79	1.78	1.76	1.75	1.74	1.73
14	1.71	1.70	1.69	1.68	1.66	1.65	1.64	1.63	1.62	1.61
15	1.60	1.59	1.58	1.57	1.56	1.55	1.54	1.53	1.51	1.51
16	1.50	1.49	1.48	1.47	1.46	1.45	1.44	1.44	1.42	1.41
17	1.41	1.40	1.39	1.39	1.38	1.36	1.36	1.35	1.34	1.33
18	1.33	1.32	1.31	1.31	1.30	1.30	1.29	1.29	1.28	1.27
19	1.26	1.25	1.25	1.24	1.24	1.23	1.22	1.21	1.21	1.20
20	1.20	1.19	1.19	1.18	1.18	1.17	1.16	1.16	1.15	1.15
21	1.14	1.14	1.13	1.12	1.12	1.11	1.11	1.10	1.10	1.10
22	1.09	1.09	1.08	1.08	1.07	1.07	1.06	1.06	1.05	1.05
23	1.04	1.04	1.04	1.03	1.03	1.02	1.02	1.01	1.01	1.00
24	1.00	1.00	.99	.99	.99	.98	.98	.97	.97	.96
25	.95	.95	.95	.94	.94	.93	.93	.93	.92	.92
26	.92	.92	.91	.91	.91	.90	.90	.90	.89	.89
27	.89	.89	.88	.88	.88	.87	.87	.87	.86	.86

(Table shows glucose percentage.)

It is becoming customary in Louisiana to entirely neglect the determination of glucose in sugar-house analysis. The writer is of opinion, however, that a knowledge of the glucose content of the juices, syrups, etc., affords valuable criteria for sugar-house control which well repays the trouble of carrying out such a glucose determination as has been described.

CHAPTER IV.

A Modification of the Clerget Method of Determining Sucrose in Molasses.

(Wm. E. Cross and W. G. Taggart.)

The importance of determining the true purity of molasses is well recognized in sugar-house control work, and yet the methods commonly used at present are neither so rapid nor so accurate as would be wished.

The use of the refractometer in total solids estimation eliminates the old prolonged drying method for sugar-house purposes, while at the same time ensuring accurate results. The other factor in purity determination, the sucrose value, can also be determined with accuracy and comparative ease if proper methods are used. In this paper we shall present a study of the accurate determination of the sucrose.

In the ordinary method of clarification of the molasses solution with lead subacetate, instructions are always given to add just sufficient of the agent necessary to effect clarification, owing to the effect of the excess of lead on the rotation of the sugars of the molasses, especially on the levulose. This excess of lead, as was shown so far back as 1871, leads to the formation of lead levulosate, etc., which decreases the negative rotation, and consequently causes an increase in the apparent dextro-rotation of the solution. Under certain conditions this lead compound is

insoluble, but these conditions are not often met with in sugar-house work, where only a slight excess of lead is usually employed.

As we have stated, most methods for the analysis of molasses at present in use, recommend the avoidance of excess as far as possible, and if excess be used, do not offer any means of eliminating this error. The official A. O. A. C. methods are a case in point. It is obvious, however, that in practical work excess is bound to be used at times, and the error thus produced ought certainly to be corrected for if possible.

Spencer (1) recommends that a slight excess of lead be used, and that the error be eliminated by acidifying with acetic acid before taking the single polarization. This method is reasonably reliable, when the excess is kept within certain limits.

In Table I some results showing the modification introduced by the acetic acid correction are given:

TABLE I.

Solution	Amount Dry Lead to 100 cc.	Single Polarization	Single Polarization after acetic acid added
Molasses $\frac{N}{4}$	1 g.	32.80	32.56
	2 g.	32.80	32.56
$\frac{N}{1}$	6 g.	32.6	32.34
Syrup $\frac{N}{2}$	1 cc. subacetate solution	50.1	49.9
Syrup $\frac{N}{2}$	3.0 g.	30.0	29.4

In the ordinary methods of molasses analysis, however, there is another source of error which does not claim much attention ordinarily. If the solution is half normal, the clarification, when excess of lead is avoided, or "slight", as Spencer recommends, is so incomplete that only dark colored solutions are obtained,

(1) Handbook for Sugar Manufacturers, p. 150.

which only admit of approximate polarization even in a 10 cm. tube. Even with quarter-normal solutions, with some molasses, the polarization reading under the same conditions is only an approximate one, and the error is here multiplied by four in the calculation. Our first efforts, therefore, should be directed towards obtaining a solution sufficiently clarified to admit of easy reading, as in this way the sometimes very serious error above mentioned will be eliminated.

A better clarification could be obtained by the use of a large excess of lead, if this were permissible. Although this seems to be somewhat against the traditions of sugar work, it has been rightly pointed out by Tervooren (2) that even though an excess of lead remove part of the levulose from solution this is a matter of no consequence in the Clerget determination, where the true sucrose is to be found. The effect of the excess of lead on the rotation of the levulose still in solution would have to be eliminated, of course, and Tervooren has elaborated a method by which a large excess of lead subacetate solution is added to effect adequate clarification, after which the lead levulosate in solution is decomposed by the addition of acetic acid and alumina cream. Tervooren uses what amounts to a half normal solution. Here with the large excess of lead used, a large lead precipitate may be expected, and if the volume occupied by the lead precipitate affects the results, as has been claimed by Deerr, Wiechmann and others, and as has been fairly conclusively proved by Horne (3), the error introduced by a larger precipitation of lead will be considerable. To avoid this error as far as possible, Deerr (4) recommends using very dilute solutions (sixth normal), thus obtaining a large volume of solution in comparison with which the volume of the lead precipitate is entirely negligible. In order to avoid too much multiplication of the error of reading, moreover, Deerr recommends also the use of long tube (60 cm.) for the polariscope. Reading a sixth normal solution in a 60 cm. tube gives the same result as that from a half normal solution in a 20 cm. tube, and the multiplication of the error in reading is thus avoided. The invert reading is also taken in a 60

(2) Java Archief. 1902. 321. See also N. Deerr, Haw. Bull. No. 31 (1910).
(3) J. Am. Chem. Soc. 1907. 926.
(4) Hawaiian Bulletin 31 (1910).

cm. tube, and in his method no attempt (as far as can be gathered from his report) is made to remove the lead in solution, the inference being that the volume occupied by the lead chloride precipitate will also be considered negligibly small in so great a volume of liquid.

The very serious drawback to the use of this method is the necessity of employing long tubes, as practically all the polariscopes in use in Louisiana are unable to accommodate a 60 cm. tube, and indeed there are many in use for which a 40 cm. tube would be too long. Furthermore, in the use of such long tubes the work is awkward, and far less convenient than when shorter tubes are used; but with such high dilution as Deerr recommends these lengths are essential for accurate results. It therefore seemed desirable to study whether the same principle (that of Tervooren above mentioned) could not be used in a method which did not entail such high dilutions, and consequent use of long tubes.

The entire question depends upon the influence of the volume occupied by the lead precipitate. This influence can, however, be entirely eliminated by the use of the dry lead clarification (see Chap. II), in which method the solution is made up to the mark first, and the dry lead subacetate then added. Previous work on the question of clarification with dry lead having shown the reliability of the method, we proceeded to investigate the possibility of using the principle of Tervooren in this connection. In this way it was found that very good results could be obtained by adding a considerable excess of dry lead to clarify the half normal solution of syrups, molasses, etc. In this way quite a dark molasses could be read easily in a 20 cm. tube. It was found that the clearness of the solution did not increase continually with the amount of the lead added in excess, but that after a certain proportion of lead had been added the solution had already reached approximately its maximum clarification, so that there was no reason to add more than this amount of lead. A little practice showed approximately when this point was reached with the different grades of molasses, syrups, etc.; indeed, we found that the amount of lead required varied from 2 gm. with syrups to 6 gm. with low-grade molasses (per 100 cc. half nor-

mal solution). As the solution suffered no further dilution after being made half normal (except the 50-55 dilution in the Clerget operation) the error in reading (in 20 cm. tubes), which, owing to the clearness of the solution, is very small, also suffers multiplication by two only, and so is kept down within small limits.

While the volume of the lead precipitate has no influence on the single polarization with this method, the presence of dissolved lead in considerable concentration was likely to have serious effects on the Clerget results, so that it was necessary to remove the lead from solution before the hydrochloric acid for inversion was added. Owing to the high concentration of the lead, the addition of potassium sulphate or oxalate would leave potassium salts in the solution in such concentration as to incur serious risk of modifying the rotation of the sugar solution. Much experimentation and consideration of the matter lead us to the conclusion that *oxalic acid* could be used as a substitute both for the acetic acid used before the single polarization and for the potassium sulphate or oxalate necessary for removing the lead. In this way no metallic ions would be introduced into the solution, although the removal of the lead would be adequately effected; and moreover by using dry finely powdered oxalic acid, no dilution of the solution would be necessary. In this way a method at once simple and reliable was elaborated as follows: Normal weight of molasses is dissolved and made up to 200 cc. A convenient quantity of this is treated with the necessary excess of dry lead subacetate and filtered. To the filtrate is added sufficient dry finely powdered oxalic acid* to precipitate almost all the lead present in solution, and the mixture refiltered.¶ The single polarization and Clerget determinations are made with this solution.

The single polarization results obtained after acidification with oxalic acid were approximately the same as those obtained by using acetic acid, as the following table shows:

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* The dry, finely powdered dehydrated oxalic acid is obtained by heating the powdered C. P. acid to 70° C. for some time and regrinding. Keep in a stoppered bottle.

¶ If too much oxalic acid is added, the filtration is rendered difficult.

TABLE II.

Solution	Amt. Lead Subacetate	Alkali Polarization	Acidified with Acetic Acid	Acidified with Oxalic Acid
Molasses $\frac{N}{1}$	6 g.	32.6	32.34	32.50
	9 g.	33.4	32.34	32.50
Molasses $\frac{N}{4}$	1 g.	8.20	8.14	8.10
	2 g.	8.20	8.14	8.05
Syrup $\frac{N}{2}$	....	18.7	18.65	18.65
Syrup $\frac{N}{2}$	....	30.0	29.48	29.6

In order to test the accuracy of the method to the best advantage, a number of syrups were analyzed in the first place, as with these the ordinary method of clarification were so good that entirely reliable and accurate results could be obtained in this way, and reliable criteria with which to compare the results of the new method were thus furnished. The values obtained showed that the new method in every case gave the same results as the standard method within the limits of experimental error.

TABLE III.

Dilution	Lead	cc. Acetic Acid	Oxalic Acid (gms.)	Single Polarization. Alk. Sol.	Single Polarization. Acid Sol.	I. R. with Lead present	Temperature	I. R. with Lead removed	Temperature	Normal S. P.	Sucrose Clerget
SYRUP											
Old method 26–100	1 cc. sub.	1	....	25.05	24.95	19.3	20.5	....	....	49.9	53.17
New method											
26–200	0.2 DL¶	..	0.10	25.0	25.0	9.5	20.5	9.5	20.0	50.0	52.90
26–200	0.5 DL	..	0.20	25.0	25.0	9.5	20.0	9.5	20.0	50.0	52.90
26–200	1.0 DL	..	0.50	24.9	24.9	9.6	20.0	9.5	20.0	49.6	52.40
26–200	2.0 DL	..	0.50	25.1	24.9	9.5	20.0	9.5	20.0	49.8	52.75
26–200	*4.0 DL	..	0.50	25.2	24.95	9.5	20.0	9.5	20.0	49.9	52.83
26–200	6.0 DL	..	0.50	25.5	25.0	9.25	20.0	9.2	19.0	50.0	52.21
26–200	8.0 DL	..	0.50	25.7	25.0	9.1	20.0	9.2	20.0	50.0	52.41
26–200	10.0 DL	..	0.50	25.8	25.0	9.0	20.0	9.0	20.0	50.0	52.08
26–200	12.0 DL	..	0.50	26.0	25.2	9.0	20.0	9.0	20.0	50.0	52.38
SYRUP											
Old method 26–200	2 cc. sub.	1	....	....	18.65	....	....	7.5	19.0	37.30	39.97
New method											
26–200	0.5 DL	..	0.20	18.7	18.65	....	....	7.5	19.0	37.4	39.97
26–200	1.0 DL	..	0.50	18.7	18.65	....	....	7.5	19.0	37.4	39.97
26–200	2.0 DL	..	0.50	18.6	18.50	....	....	7.5	19.0	37.0	39.77
26–200	*4.0 DL	..	0.50	18.7	18.50	....	....	7.5	19.0	37.0	39.77
26–200	6.0 DL	..	0.50	18.7	18.30	....	....	7.5	19.0	36.6	39.47
26–200	8.0 DL	..	1.00	18.8	18.40	....	....	7.5	19.0	36.8	39.61
26–200	10.0 DL	..	1.00	19.0	18.40	....	....	7.4	19.0	36.8	39.61
26–200	12.0 DL	..	1.0	19.2	18.4	....	....	7.5	19.0	36.8	39.61
SYRUP											
Old method	4 cc. sub.	1	....	16.3	16.28	8.9	20.0	8.8	20.0	32.56	38.91
New method											
26–200	4.0	..	0.50	....	16.28	8.9	20.0	8.8	20.0	32.56	38.74
26–200	*4.0 DL	..	0.50	16.4	16.10	8.2	20.0	8.6	20.0	32.2	38.14
SYRUP											
Old method 26–200	3 cc. sub.	1	....	15.0	14.74	....	....	9.2	19.0	29.48	38.40
New method											
26–200	*3.0 DL	..	0.10	14.9	14.80	....	....	10.2	18.0	29.60	38.54
26–200	6.0 DL	..	0.20	15.4	15.00	....	....	9.5	18.5	30.0	37.77
26–200	6.0 DL	..	0.50	15.4	15.00	....	....	9.4	20.0	30.0	37.82
26–200	6.0 DL	..	1.00	15.4	15.00	....	....	9.6	19.5	30.03	8.15

*At this point sufficient excess of lead had been added to produce a maximum clarification. ¶Dry lead.

Before a discussion of these figures is attempted, some results obtained on molasses will also be given:

TABLE IV.

Dilution	Lead	cc. Acetic Acid	Oxalic Acid (gms.)	Single Polarization. Alk. Sol.	Single Polarization. Acid Sol.	I. R. with Lead present	I. R. with Lead removed	Temperature	Normal S. P.	Sucrose Clerget
a. Molasses										
26–200.....	1.0 DL	....	0.5	15.0	14.7	....	10.4	21.0	29.4	39.16
26–200.....	3.0 DL	....	1.5	15.0	14.7	....	9.7	21.0	29.4	38.45
26–200.....	†6.0 DL	....	3.0	15.0	14.8	....	9.5	20.0	29.6	37.68
26–200.....	9.0 DL	....	4.5	16.5	14.75	....	9.4	20.0	29.5	37.44
b. Molasses										
26–200.....	12 cc.									
26–200.....	sub sln.	1	....	17.8	16.88	....	9.8	....	34.76	42.03
26–200.....	†6.0 DL	....	0.5	17.8	17.60	....	9.8	....	35.20	42.35
26–200.....	12.0 DL	....	0.5	18.8	18.25	....	9.8	....	36.5	42.30
c. Molasses										
26–200.....	6.0 DL	....	0.5	‡	10.0	10.4	10.0	....	20.0	32.05
26–200.....	8.0 DL	....	0.5	10.0	9.9	10.0	10.0	26.0	19.8	31.90
26–200.....	†12.0 DL	....	0.5	10.4	9.9	9.0	9.4	....	19.8	30.90
26–200.....	15.0 DL	....	0.5	10.6	10.0	....	9.0	....	20.0	30.38

†Sufficient lead for maximum clarification.
‡Too dark.

TABLE V.

Solution	Amount Dry Lead Subacetate to 100 cc.	Single Polarization			D.–I.				
		A—Direct	B—With Acetate Acid	C—With Oxalic Acid	Sp. A—I (lead present)	Sp. B—I (lead present)	Sp. A—I (lead removed)	Sp. B (lead removed)	Sp. C (lead removed)
Molasses in 100 cc. $\frac{N}{4}$	½ g	8.25	8.25	8.10	13.53	13.53	13.52	13.52	13.32
				8.05					
	*1 g	8.20	8.14	8.10	13.45	13.39	13.44	13.36	13.29
		8.20	8.14	8.10					
				8.00					
	2 g	8.10	8.14	8.05	13.43	13.40	13.49	13.34	13.27
				8.10					
				8.00					
	3 g	8.35	8.10						
		8.40	8.10	8.18	13.49	13.49	13.21	13.49	13.29
	6 g	9.10	8.25	8.2	14.10	13.25	14.20	13.25	13.30

*Sufficient lead for maximum clarification.

TABLE VI.

Solution	Amt. lead sub acetate to 100 cc.	Single Polarization			D.-I.	
		A. Direct	B. Acetic acid	C. Oxalic acid	Sp. A—I (lead present)	Sp. C—I (lead absent)
Molasses N/1	3 g	16.15	16.15	32.48	26.38	26.41
	*6 g	32.60	32.34	32.50	26.54	26.26
	9 g	33.40	32.34	32.50	26.70	26.10
	12 g	33.75	32.80	32.80	27.12	26.025
	20 g	36.00	33.20	32.00	....	24.80

*Sufficient lead for maximum clarification.

In Table III the results obtained on syrups are shown. With syrups the ordinary clarification is very good, and the results therefore are reliable and may be taken as standard. The results obtained from the new method, using excess of lead and oxalic acid, are a very good "check" as long as the excess of lead is not too great, but as this excess increases, a very slight fall in the Clerget value obtained seems to be produced. It will be noticed that as the excess of lead becomes greater, the single polarization increases, but this error seems to be removed almost entirely by acidifying the solution.

The experiments with molasses gave similar results. Only in rare instances did the acid single polarization increase as greater amounts of lead were added (e. g., Table IV b.) and although in some instances well marked decreases were observed in the Clerget value as the amount of lead increased (e. g., Table IV and Table VI). This is a point of considerable importance. Deerr states that the (D-I) value is entirely independent of the amount of excess of lead. This is not confirmed by our experiments, as under our conditions, working of course with the dry lead, a slight decrease in the Clerget value seemed always to result when the excess of clarifying agent became too large. As was stated previously, however, no benefit is derived from a large excess of lead, a maximum clarification being obtained when

a certain comparatively small excess is added, and the figures for the Clerget result obtained under these conditions agree very well with those obtained with ordinary clarification, even with syrups.

The experimental error of the new method is considerably lower than that with the ordinary one, in that the clarification is better, and therefore more certain and definite readings can be obtained. Moreover, the results obtained not only conform with those from the ordinary method, but also with each other.

It was interesting to study the influence of the presence of the lead chloride in the inverted solution. As will be seen from Tables III, IV and V no special change in the Clerget values could be found due to this cause.

A useful addition to the process was the employment of zinc dust to decolorize the inverted (acid) solution. In no case did we find this to introduce error into the results, while we were enabled in this way to increase the accuracy in polarizing the invert solution enormously.

In Table VII will be found a record of a number of analyses of molasses, syrups, etc., by both methods, showing the close agreement between the results obtained. As the results agree well on syrups where the ordinary method of clarification is sufficient, it may be said that the results with excess of lead on molasses are probably more accurate than those from the ordinary clarification, as here the error in reading the dark solution of the ordinary method is often fairly large.

TABLE VII.

Description of Sample	ORDINARY METHOD		NEW METHOD	
	Dilution	Clerget	Dilution	Clerget
Syrup A	N/2	53.17	N/2	52.83
Syrup B	N/2	39.97	N/2	39.77
Syrup C	N/2	38.91	N/2	38.14
Syrup D	N/2	38.40	N/2	38.54
Molasses A	N/2	39.16	N/2	37.68
Molasses B	N/2	42.03	N/2	42.35
Molasses C	N/2	40.3	N/2	40.2
Molasses C	N/4	40.46	N/4	40.0
Molasses D	N/1	28.0	N/1	28.0
Molasses E	N/2	28.15	N/2	28.51
Molasses F	N/2	40.83	N/2	40.67
Molasses G	N/1	38.70	N/1	38.55
	N/2		N/2	

The method of inversion used was a modification of the official one of the A. O. A. C. (6). Fifty cc. of the filtrate after the clarification are taken, and 5 cc. conc. HCl added. After mixing, the flask is heated in a water bath at 70° C. The temperature of the flask should reach 67°-69° within 2½ to 3 minutes, and the flask solution should remain at this temperature thereafter for 7-7½ minutes, making a maximum total time of heating of 10 minutes. Thereupon the flask is quickly cooled to the temperature of reading the single polarization (20° C. if

(6) Bull. 107 (Rev.) Bureau of Chemistry, Washington, D. C.

possible) and polarized. Sucrose is calculated by the following formula:

$$S = \frac{100\,(P-I)}{142.66 - t}{2}$$

S = % Sucrose.
P = Direct reading.
I = Invert reading.
t = Temperature.

In conjunction with this, for accurate work, the modified factors given by Herzfeld must be used, the factors changing with the concentration of the sugar in solution. The following is Herzfeld's table:

TABLE VIII.

Grams Sugar per 100 cc.	Clerget Constant	Grams Sugar per 100 cc.	Clerget Constant
1	141.85	11	142.53
2	141.91	12	142.59
3	141.98	13	142.66
4	142.05	14	142.73
5	142.12	15	142.79
6	142.18	16	142.86
7	142.25	17	142.93
8	142.32	18	143.00
9	142.39	19	143.07
10	142.46	20	143.15

If the original Clerget method of heating be followed, in which the flasks are heated 15 minutes in a water bath, the temperature rising slowly and attaining 68° C. at the end of the 15 minutes period, the factor is 144 for solutions reading 80° V., in a 200 mm. tube, and has been shown by Deerr (7) to vary according to the following table:

(7) Bull. 31, Hawaii (1910)

TABLE XI.

Direct Reading in 20 cc. tube.	Value of Constant	Direct Reading in 20 cc. tube.	Value of Constant
100	144.5	50	143.3
95	144.3	45	143.2
90	144.2	40	143.1
85	144.1	35	142.9
80	144.0	30	142.8
75	143.9	25	142.6
70	143.8	20	142.5
65	143.7	15	142.3
60	143.6	10	142.2
55	143.4	5	142.1

The error introduced by avoiding this correction is usually about two or three tenths per cent and is therefore well within the experimental error, but in all accurate work, of course, it may not be omitted.

SUMMARY.

The methods of analysis of molasses in general use in this country recommend the use of no excess or at most a slight excess of lead in clarification, and in this way often very imperfect clarification is obtained. Often an excess is employed of necessity, without means being taken to eliminate the error due to this excess. Better results are yielded when, following Tervooren, a sufficiently large excess is used to bring about a maximum clarification and decolorization. With such a large excess, however, the influence of the volume occupied by the lead precipitate is probably considerable and Deerr eliminates the error thus produced by using solutions of high dilution (sixth normal) and polarizing in long tubes (60 cm.). This method is, however, impractical for sugar-house work in Louisiana, as well as being somewhat awkward in any case. Another way to eliminate the influence of the lead precipitate is by the use of dry lead subacetate clarification, and we have used Tervooren's principle along with this clarification method with very satisfactory results. In the method we devised, an excess of dry lead is added to the half normal molasses solution and after filtering the ex-

cess of lead is removed by adding approximately the right amount of dry finely powdered oxalic acid. After filtration the well decolorized, lead-free liquid is polarized, single and Clerget. It was found that too great an excess of lead should be avoided, as the Clerget result falls slightly after a certain excess has been reached. The maximum decolorization, however, is produced by an excess which is too small to affect the Clerget result in this way. Our results confirmed also those of previous investigators in showing the increase in polarization brought about by excess of lead in alkaline solution, and also in showing that the normal polarization is usually restored by acidifying the solution. The use of small quantities of zinc dust in decolorizing dark inverted solutions is recommended. In conjunction with the method advanced above, the factor for Clerget determination should be modified for varying concentrations of sucrose according to the tables given.

It is, of course, assumed in all Clerget analysis that the single and invert readings are taken at the same temperature.

CHAPTER V.

The Effect of Urea and Betaine on the Rate of Inversion of Sucrose by Hydrochloric Acid.

(The Andrlik urea method of polarization for cane products.)

(Wm. E. Cross and W. G. Taggart.)

In the ordinary Clerget determination of true sucrose in molasses and other low sugar products there is one source of error which has so far not been circumvented: the fact that the single polarization is taken in neutral, the invert polarization in acid solution.

The error is caused by the effect of the acid on substances other than the sucrose originally present in the molasses; and as in cane products large proportions of invert sugar are present besides the ordinary non-sugars, this error is probably greater here than with beet products. For beet molasses Andrik (1) has recommended taking the single polarization in acid solution of the same concentration as in the invert reading, the inversion of the sucrose at ordinary temperature being prevented for a few minutes by the addition of urea or betaine. Pellet (2) recommends this method also for cane products, and we have therefore been led to investigate the method from the cane standpoint.

In the first experiments the retarding action of betaine was studied. In the one case 50 cc. of a normal sucrose solution was taken, 5 cc. HCl (sp. gr. 1.18) added and the mixture diluted to 100 cc. and the fall in polarization on standing (at 28%) measured. In the second case, 50 cc. of normal sucrose solution, 10 cc. of a solution containing 5 cc. HCl (sp. g. 1.18)+5g. betaine, was made up to 100 cc. and polarized. The results were as follows:

(1) Zeitsch Zuckerind Bohm. 31, 417.
(2) I. S. J. 13, 206.

TABLE I.

Time	A Sucrose + 5% HCl Polarization		B Sucrose + 5% HCl + 5% betain. Polarization	
	I (28° C.)	II (26° C.)	I (28° C.)	II (28° C.)
After 1.5 mins.....	24.5	24.5	...	...
" 2 "	...	...	24.4	24.5
" 3 "	24.1	24.2	24.0	24.3
" 4 "	23.7	24.0	23.6	24.0
" 5 "	23.4	23.7	23.2	23.6
" 6 "	22.95	23.5	22.8	23.3
" 7 "	22.5	23.0	22.5	23.0
" 8 "	22.0	22.2	22.1	22.7
" 9 "	21.8	22.6	21.7	22.3
" 10 "	21.4	22.3	21.4	21.9
" 11 "	21.0	21.8	21.1	21.7
" 12 "	20.7	21.5	20.8	21.3
" 13 "	20.4	21.3	20.5	21.0
" 14 "	20.1	21.0	20.2	20.8
" 15 "	19.8	20.7	20.0	20.4
" 20 "	18.5	19.5	18.5	19.0
" 25 "	17.0	18.5	17.2	17.4

The values in experiments AI and BI were plotted, and gave the curves shown in Fig. I.

From these values it is apparent that at the temperature used (28° C.) the betaine was almost entirely without retarding action on the inversion of the sucrose. Similar experiments were carried out with urea. The solution containing urea contained 50 cc. normal sucrose solution, + 10 cc. of a solution containing (in 10 cc) 5 cc. HCl (sp. g. 1.18)+5g. urea in 100 cc. The other solution contained 50 cc. normal sucrose solution + 5 cc. HCl (sp. g. 1.18) in 100 cc. (i. e., without the urea). The fall in polarization of these solutions was also followed out at 28° C.

FIG. I.

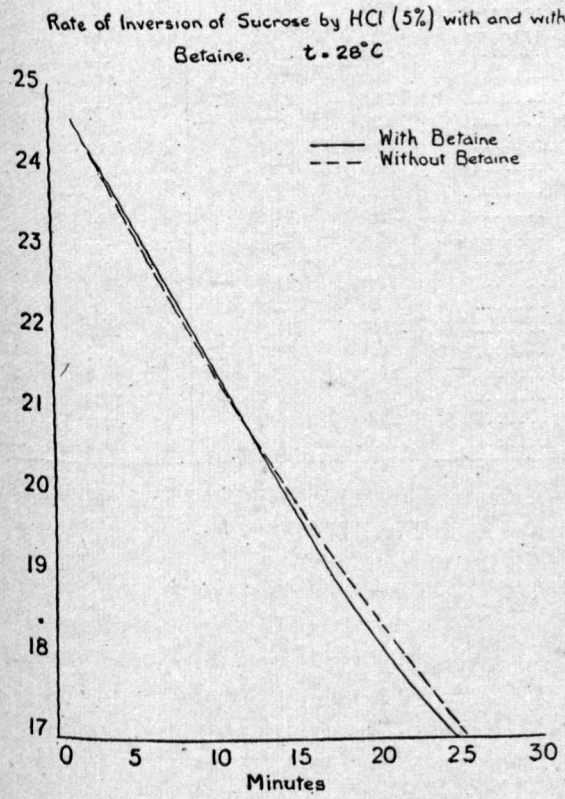
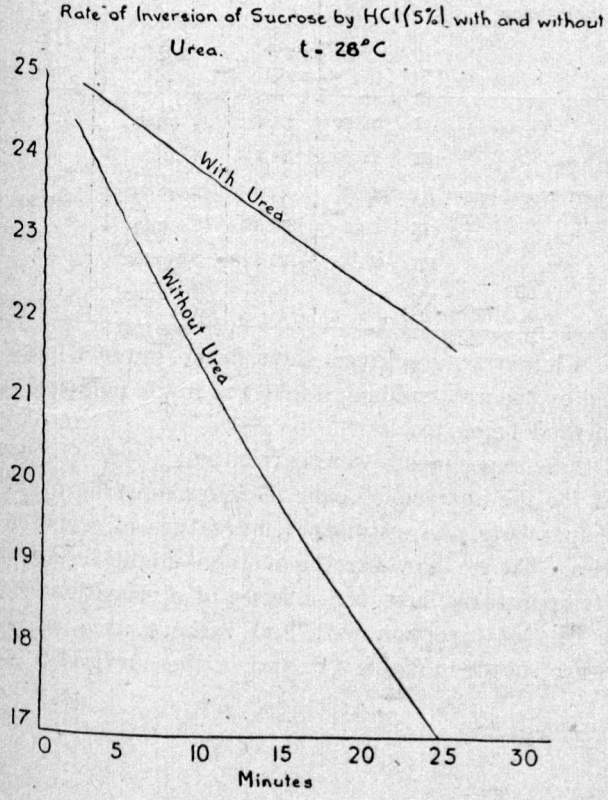

Rate of Inversion of Sucrose by HCl (5%) with and without Betaine. t = 28°C
With Betaine
Without Betaine
25
24
23
22
21
20
19
18
17
0
5
10
15
20
25
30
Minutes

TABLE II.

Time	Sucrose + 5% HCl Polarization		Sucrose + 5% HCl + 5% urea Polarization	
	I (28° C.)	II (26° C.)	I (28° C.)	II (28° C.)
After 1.5 mins.....	24.5	24.5	...	25.0
" 2 "	...	...	...	24.9
" 2.5 "	...	...	24.9	...
" " "	24.1	24.2	...	...
" 4 "	23.7	24.0	24.7	24.6
" 5 "	23.4	23.7	...	24.4
" 5.5 "	...	...	24.5	...
" 6 "	22.95	23.5	...	24.2
" 6.5 "	...	...	24.3	...
" 7 "	22.5	23.0	24.2	24.0
" 8 "	22.0	22.8	24.1	...
" 8.5 "	...	...	...	23.8
" 9 "	21.8	22.6	24.0	...
" 10 "	21.4	22.3	...	...
" 10.5 "	...	...	...	23.45
" 11 "	21.0	21.8	23.75	...
" 11.5 "	...	...	...	23.3
" 12 "	20.7	21.5	23.5	...
" 13 "	20.4	21.3	...	23.1
" 14 "	20.1	21.0	23.3	23.0
" 15 "	19.8	20.7	23.2	22.85
" 20 "	18.5	19.5	22.3	22.1
" 25 "	17.0	18.5	21.8	21.4

The value obtained in experiments AI and BI were plotted and gave curves as in Fig. II

FIG. II.


Rate of Inversion of Sucrose by HCl (5%) with and without Urea. t - 28°C
25
24
23
22
21
20
19
18
17
With Urea
Without Urea
0
5
10
15
20
25
30
Minutes

It is seen that urea retards the inversion to some extent, but that this retardation is insufficient to allow of the single polarization being obtained before the inversion sets in. Some experiments on this point gave results shown in Table III.

TABLE III.

Substance		True Single Polarization	By Urea Method		Clerget	Urea Clerget
			Single pol.	Time		
Sucrose	I	25.00	24.7	4 mins.		
	II	25.00	24.6	4 mins.		
Sucrose and invert sugar	I	38.3	38.0	2 mins.	39.84	39.6
	II	38.3	37.95	1.5 mins.		
	III	38.45	38.0	3.5 mins.		
	IV	38.3	38.01	1.5 mins.		

The Clerget values given showed the lower Clerget results obtained by the urea method, due to the single polarization by the urea method being too low.

All these experiments were carried out at 28° C. because any method for the analysis of cane molasses must be practicable at this temperature, the ordinary temperature of working in cane countries. To see how far the method might be applicable at lower temperatures, however, a series of observations were made on the rate of inversion with and without urea, at 20°. The results are shown in Table IV, and in the curve of Fig. III.

F|7. III.

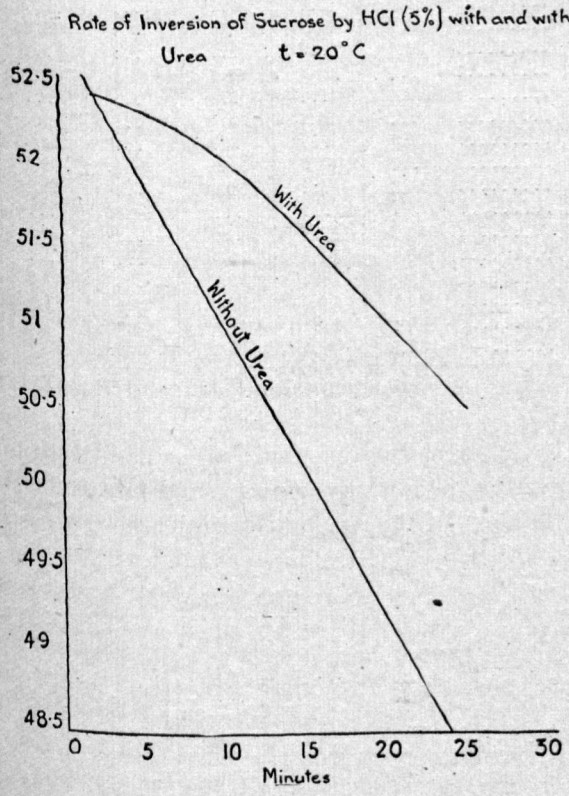

Rate of Inversion of Sucrose by HCl (5%) with and without Urea t = 20°C
52·5
52
51·5
51
50·5
50
49·5
49
48·5
With Urea
Without Urea
0
5
10
15
20
25
30
Minutes

TABLE IV.

(t = 20°.)

Time	Sucrose + 5% HCl Polarization			Sucrose + 5% HCl + 5% Urea Polarization		
	I	II	III	I	II	III
After 2 mins.....	...	52.9	52.5	52.5	52.5	
" 2.5 "	52.5	...	...	...	...	
" 3 "	52.0	...	52.2	...	52.4	
" 3.5 "	...	52.6	...	...	...	
" 4 "	51.5	...	...	...	...	
" 5 "	51.6	52.4	52.0	52.4	52.35	
" 6.5 "	51.3	...	...	...	...	
" 7 "	...	51.9	51.6	52.35	52.3	
" 7.5 "	51.0	...	...	...	...	
" 8 "	...	51.8	51.4	...	...	
" 9 "	50.7	...	...	...	52.05	
" 10 "	...	51.6	51.0	52.1	52.0	
" 11 "	50.5	...	50.95	...	51.95	
" 11.5 "	...	...	...	51.85	...	
" 12 "	50.2	...	...	...	51.9	
" 13 "	50.1	51.1	50.5	...	...	
" 14 "	...	...	50.3	...	51.7	
" 15 "	49.7	50.5	50.1	51.4	51.65	
" 20 "	49.4	50.1	49.1	50.6	51.0	
" 25 "	48.7	47.1	48.2	49.9	50.5	

Plotted values of experiments A (III) and B (II) given in Fig. III.

Thus it is apparent that even at the comparatively low temperatures of 20° C., the inversion sets in before sufficient time has elapsed to allow of the single polarization beng measured.

TABLE V.

(t=20° C.)

Solution	True S.P.	Urea Method	Time	Clerget	Urea Clerget
Pure Sucrose	99.9	99.11	4 min.	100.00	99.41
	....	99.11	4 min.	....	....
	....	98.78	7 min.	....	....
	....	98.34	9 min.	....	....
	....	98.01	10 min.	....	....
Sucrose 96%	93.9	93.61	4 min.	95.97	95.75
Invert sugar 4%	....	93.28	7 min.	....	....
	....	92.90	9 min.	....	....
	....	92.73	10 min.	....	....
	93.9	93.50	4 min.	....	....
	....	93.17	7 min.	....	....
	....	92.62	9 min.	....	....
	....	92.40	10 min.	....	....

Results of analyses at 20° C. of sugar solutions by the ordinary and the urea method are given in Table V. It is seen that the single polarization by the urea method is always too low, due to partial inversion of the sucrose, and that the Clerget results are also too low in consequence. The results of Table V also emphasize the importance of the time element; if the single polarization of the first solution were taken after 4 minutes it would be 99.11, if in 7 minutes, 98.56, and the Clerget results are modified accordingly.

Thus it is shown that the retarding influence of Betaine and Urea on the rate of inversion of sucrose is only slight at 28° C., and even at 20° C., and therefore that analytical methods based on this retarding influence cannot be accurately applied in cane work.

CHAPTER VI.

The Direct Determination of Sucrose in Presence of Reducing Sugars.

(Wm. E. Cross and W. G. Taggart.)

The problem of the direct determination of sucrose in presence of reducing sugars has occupied chemists for many years, unfortunately without successful issue.

The Clerget or inversion method gives results of good accuracy, but it is difficult to execute properly, and also takes much time, being perhaps the most difficult and lengthy determination used in sugar-house control work. The great advantage, therefore, that would be found in a short direct method of sucrose determination in products containing reducing sugars has been universally acknowledged, but despite much research in this direction no such method has as yet been worked out satisfactor-

ily. The line of attack mainly adopted has been that first proposed by Dubrunfaut (1), which consisted in destroying the reducing sugars with alkalies, and determining the sucrose left in the solution by direct polarization. Dubrunfaut claimed that the products of the action of alkalies on the reducing sugars were optically inactive, but Pellet (2) and others maintained that the activity of the reducing sugars was not entirely destroyed by Dubrunfaut's method. Much other work was carried out by Koydl (3), Jesser (4) and others with the idea of perfecting Dubrunfaut's method, but they were unsuccessful in their attempts. Experiments in another direction were made by Bodenbender (5), who sought to determine colorimetrically the amount of reducing sugar destroyed, by measuring the color of the alkaline solution. This never claimed much attention, however. More recently Jolles (6) recommended a modification of Dubrunfaut's method for products containing two or three per cent of reducing sugars only, but this method met with considerable criticism. Then followed an article by Lemeland (7) in which still another modification was recommended. In a recent paper (8) Lemeland and Pellet submitted an improvement of this method, for which very accurate results were claimed with molasses and other sugar-house products. In a still later article (9) Pellet, Fribourg and Bohain publish further results obtained by this method, on cane and molasses, which show very good agreement with the results from the inversion method.

The new method of Pellet and Lemeland is as follows (8):

"(1) Make a solution of the cane molasses that will contain at most 5 per cent of reducing sugars. (For example, suppose the molasses contains 40 per cent of sucrose, and 15 per cent of reducing sugars, 30 grms. in 100 cc. or 60 grms. in 200 cc. should be used.) (2) Measure 50 cc. of this solution into a 300 cc. flask, add 7.5 cc.

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(1) Comptes. Rendus, *32*, 439.
Suc. Ind., *4*, 203.
(2) Bull. Assoc. Chim. Sucr., *8*, 623.
(3) Oestr. Ung. Zeit., *29*, 381.
(4) Oestr. Ung. Zeit., *27*, 35.
(5) Deut. Zuckerind., *9*, 1302.
(6) Zeit. Unters. Nahr. Genussm., *20*, 631.
(7) Jl. Pharm. Chim., *2*, 298.
(8) I. S. J., *13*, 616.
(9) I. S. J., *14*, 181.

of sodium hydroxide (36° Bé.), then 75 cc. of hydrogen peroxide (12 vols.), and 60 cc. of water. (3) Mix and place the flask in a boiling water bath for 20 minutes. (4) Cool, neutralize the remaining alkalinity fairly exactly with acetic acid, and defecate with basic lead acetate solution (36° Bé.), the amount of which necessary will be found to vary from 15 to 40 cc. according to the weight of the material taken, the amount of reducing sugars destroyed, and the impurities initially contained in the liquid. (5) Complete the volume to 300 cc., mix well and filter. Polarize directly in the 200 or 400 tube."

Knowing the considerable importance of such a direct method, especially for the quick valuation of molasses in sugar-house control work we undertook to test out this method to discover whether it could be adopted and recommended for routine work. Our results were not satisfactory. In spite of much effort, and very careful attention to the details of the method, we were only able to obtain results like the following:

TABLE I.

Sample.	Sucrose Clerget	Sucrose Pellet-Lemeland.
Syrup	53.17	49.92
Syrup	39.97	37.90
Syrup	46.72	42.22
Syrup	54.66	49.40
Syrup	43.50	34.30
1st Molasses	40.00	36.40
Molasses	32.20	27.60
Molasses	40.60	35.60
Molasses	38.70	27.20
Syrup	53.17	49.20

Experiments with mixtures of sucrose, dextrose and levulose gave the following results:

TABLE II.

Sucrose Clerget.	Sucrose Pellet-Lemeland.
39.26	37.31
22.40	20.24
25.97	23.40

The results here given were confirmed by many succeeding experiments and went to show that the method of Pellet and Lemeland did not yield accurate results on molasses, syrups, etc.

Owing to the importance of such a method, if such a one could be devised, for sugar-house work, we proceeded further in the direction of modifying the method of Pellet, with the hope of getting better results.

Our next experiments were carried out to see whether changing the time of heating would give better results. No greater accuracy could be obtained in this way, however. One sample, for instance, of true sucrose content (by Clerget) 25.97, gave 23.4 by the Pellet Lemeland after 10, 15 and 20 minutes heating. The temperature of heating was next modified. An artificial mixture of sucrose, dextrose and fructose (Clerget 38.47) gave 30.92% by the Pellet-Lemeland method, 36.92 when the temperature of heating was 70° C., but when the temperature was reduced to 55° C., a result of 38.48% was obtained. Several experiments following this confirmed the fact that by heating at 55° C., instead of 100° C., as Pellet recommends, reliable results could be obtained.

Table III gives some results obtained with dilutions, etc., similar to Pellet's. A solution of 100 g. molasses in water up to 400 cc. was made, and 50 cc. of this was taken, in a 250 cc. flask, and to this was added 6.3 cc. Na OH of 36° Beaume, 75 cc. H_2O_2 (10%) and 50 cc. distilled water. The flask was immersed in a water bath (at 55° C.) for 20 minutes. The cooling, neutralizing, etc., was carried out as in Pellet's method.

TABLE III.

Name of Sample.	Sucrose Clerget.	Sucrose Direct.
Mixture of Sucrose, Dextrose, Levulose	38.65	38.48
Syrup	54.91	54.35
Syrup	53.06	52.88
Syrup	37.86	38.48
Syrup	38.32	39.00
Open Kettle Molasses	40.98	42.12
Molasses	30.11	28.60
Molasses	27.93	28.60
Molasses	28.08	28.60

We next sought to eliminate the extreme dilution the Pellet method entails. In this we were successful, as with the new temperature of heating, a dilution which made the final reading only half normal (normal in 400 cc. tube, in which the solutions were easily readable) was found to be practicable and to give accurate results.

The following is the method as finally modified by us:

Normal weight of product is weighed into a 100 cc. flask, the solution filled up to mark, and 50 cc. thereof transferred to another 100 cc. flask, where 6.3 cc. sodium hydroxide solution (36° 13), 7.5 cc. hydrogen peroxide (30% by weight, 100% by volume) is added. Careful cooling is necessary to prevent a too violent effervescence, and ether from a dropping bottle can be used to advantage in preventing excessive foaming. Cooling in cold water, or ice, is helpful in moderating the sometimes vigorous reaction. After effervescence has almost stopped the flask is kept immersed in a water bath at 55° C. for 20 minutes. Thereupon the liquid is cooled, made slightly acid with acetic acid and made up to mark. After clarification with dry lead subacetate and filtering, the solution is polarized. If polarization takes place in a 400 cm. tube the percentage sucrose is read off directly; while the use of 200 cm. tube entails multiplication of the reading by two. The solution obtained in all cases, at the end of the operation, are almost colorless and quite clear and bright.

Considerable latitude is permissible in the concentration and method of working used. In Table IV, for instance, 52 gms. of the sample were weighed out, into a 100 cc. flask, which was filled up to mark, and 25 cc. of this in a 100 cc. flask was used in the process (making a final solution half normal). In Table V, on the other hand, a three-fourth normal solution was made, and 50 cc. of this used in a 100 cc. flask in the method, so making the final solution three-eighths normal. Probably the most convenient way is to make up a normal solution, and to use 50 cc. of this in a 100 cc. flask for the destruction of reducing sugars, etc.

TABLE IV.

Product.	Sucrose Clerget.	Sucrose Direct.
Syrup	53.17	53.00
Syrup	53.00	52.40
Syrup	31.87	32.40
Syrup	54.99	54.60
Open Kettle Molasses	40.98	41.12
Molasses	27.93	28.40
Molasses	28.08	28.60
Syrup	43.43	43.40
Syrup	52.00	51.90
Molasses	35.70	35.80
Molasses	26.13	26.20

TABLE V.

Product.	Sucrose Clerget.	Sucrose Direct.
Syrup	48.26	47.73
Molasses	44.38	43.87
Molasses	39.60	40.00
Molasses	38.61	39.46
Molasses	36.50	36.66
Molasses	39.30	38.40
Molasses	29.70	29.30

The results obtained by this method have been found to be reliable and we feel that we can offer it as a substitute for the Clerget method in sugar-house work in certain cases. It could be used for the analysis of syrups and molasses in sugar-house control, especially in estimating the amount of sugar in low-grade products like hot-room goods, as a very good value for actual sucrose present is thus obtained.

We are continuing the work on other saccharine products, to determine and develop the usefulness of the method in commercial work.

The prospects of the application of the method to difficult analytical problems, like the determination of levan, raffinose, etc., are also being investigated.

CHAPTER VII.

The Acidity of Raw Cane Sugars.

The measurement of the alkalinity or acidity of raw sugars does not receive much attention in sugar analysis, and yet this determination is an important one for many reasons; particularly because the reaction of sugar has an important bearing on its keeping qualities during storage. For beet sugars in the cooler European countries the usual recommendation is that sugar should be made alkaline to prevent deterioration during storage; indeed, it is often stated that slightly alkaline sugars will keep for months without loss if other conditions are favorable. With cane sugars in moist and tropical climates, on the other hand, the case may well be different, and the fact that no very definite opinion one way or the other is obtainable goes to show that this aspect of the question is well worthy of study. Indeed if a check were kept by our chemists on the degree of acidity as well as on the keeping qualities of raw sugars, valuable information might in this way be accumulated.

The measurement of the degree of acidity is, however, a matter of considerable difficulty, as the end point is often obscured by the color of the raw sugar in solution. The question has been for many years the subject of attention here and there, especially in Germany, where sugars must be marked "alkaline" or "not alkaline" for selling purposes. A method was devised by Prof. Herzfeld, some years ago, which, however, only made the claim of distinguishing between acid and alkaline sugars. Later works on this subject showed that the method was more exact than had at first been supposed.

The method I adopted after many experiments was a modification of the Herzfeld method for beet sugars, and the results obtained went to show that in this way the degree of acidity of ordinary raw sugars could be obtained with a fair accuracy. Of course, low-grade sugars offer more difficulty, owing to the dark color of their solutions, so that here the results are more approximate.

The method here given is applicable equally to the measurement on the basis of "cc. acidity" or per cent lime equivalent, so that it can be used either way, according to preference.

Phenolphthalein.—One part pure phenolphthalein in 30 parts 90 per cent alcohol.

Neutral water.—One or two cc. phenolphthalein to each liter pure, freshly boiled distilled water. Then some of the standard alkali (made as below) is added, just sufficient to produce a plainly visible pink tinge. This should be prepared some hours before use, and not be kept more than two or three days.

Acid.—(a) (If results are to be reckoned as per cent CaO)
178.5 cc. $\frac{n}{10}$ sulphuric acid made up to 5 liters (i. e., $\frac{n}{280}$)
1 cc. is equivalent to .0001 g. CaO.

(b) (If results are to be reckoned as "cc. alkalinity")—
200 cc. $\frac{n}{10}$ sulphuric acid made up to 5 liters ($\frac{n}{250}$)
1 cc. is equivalent to .04 cc. alkalinity.

Alkali.—(a) (Results reckoned as per cent CaO).
178.5 cc. $\frac{n}{10}$ NaOH to liters. 1 cc. = .0001 g. CaO.

(b) (Results reckoned as "cc. acidity")—
200 cc. $\frac{n}{10}$ NaOH to 5 liters. 1 cc. = .04 cc. alkali.

The acid should be checked against the alkali.

TITRATION.

For ordinary raw sugars*, 10 grms. should be dissolved in the neutral water, and the solution made up to 200 cc. The titration with the alkali is best carried out in a large Erlenmeyer flask over white paper.† After a little practice the end point, indicated by a distinct pink tinge of the liquid, is fairly easily distinguishable. In an accurate titration the pink color will disappear where one or two cc. of the acid are added.

*The description here given is for acid sugars. Alkaline sugars must of course be titrated against the acid.

†By some, however, titration in a porcelain dish is preferred.

Parallel or triple titrations should be made, and if sufficient practice has enabled one to note the end-point correctly, the values obtained for the same sugar will agree very well.

For darker sugars more water should be used, 10 grms. sugar in 500 cc. being a convenient dilution. If the sugars are very dark, the accuracy of the determination is only approximate.

For results in terms of per cent CaO the $\frac{n}{280}$ solutions must be used, when 1 cc. required = .001 per cent CaO equivalent. See example I. For results in terms of "cc. acidity" the $\frac{n}{250}$ solutions should be used, when the number of cc. required multiplied by .04 gives the "cc. acidity." See example II.

EXAMPLES.

I. *First Sugar, Destrehan Plantation, Louisiana.*

10 grms. dissolved in 200 cc. neutral water.

Titrated against $\frac{n}{280}$ NaOH.

Titration (a) 14.5 cc. required.
(b) 15.5 cc. required.
(c) 15.0 cc. required.

Mean 15.0 cc.

Acidity = .015 per cent CaO (equivalent), or .53 cc. acidity.

II. *Seconds, from "Bessie K." Plantation, Louisiana.*

Darker color.

10 grms. dissolved in 500 cc. neutral water.

Titrated against $\frac{n}{250}$ NaOH.

Titration (a) 23 cc. required.
(b) 25 cc. required.

Mean 24 cc.

Acidity = .96 cc. acidity, or .027 per cent CaO (equivalent).

III. *Raw Beet Sugar (Germany).*

10 grms. dissolved in 200 cc. neutral water.

The solution had an easily discernible pink tinge, which was removed by 1 cc. of the n acid.

280

Sugar was *slightly alkaline.*

With the help of this method the acidity of a series of representative sugars was determined. It was found that with the exception of the beet sugar mentioned, all were acid to a greater or less degree.

The results obtained were as follows:

SUMMARY OF RESULTS.

Sugar.	Per Ct. CaO.	C. c. Acidity.
Louisiana Sugars—		
Destrehan Firsts	0.015	0.53
Seconds New Orleans Sugar Exchange	0.033	1.18
Gramercy Seconds	0.056	2.00
Longview Firsts	0.007	0.25
Gramercy Purged	0.008	0.29
Uncle Sam Firsts	0.007	0.28
Belle Helene Firsts	0.017	0.61
Chatsworth Firsts	0.012	0.48
Experiment Station Firsts	0.026	0.93
Seconds from Sugar Exchange	0.008	0.27
Bessie K. Seconds*	0.027	0.96
Refined Deteriorated	0.0045	0.16
Seconds New Orleans Sugar Exchange*	0.028	1.00
German Beet	Just alkaline.	
Egyptian Sugar*	0.004	0.14
Cuban Sugars* A	0.016	0.57
" " B	0.015	0.53
From San Manuel*	0.025	0.90
Nueva Luisa*	0.012	0.43
Tinguaro*	0.025	0.9
Nueva Paq.*	0.035	1.26
Mercedita*	0.022	0.79
San Antonio*	0.023	0.83
San Ignatio*	0.021	0.75
Chaparra*	0.025	0.9
Conchita	0.23	0.83

* 500 c. c. solvent used.

All the sugars were new, except the Egyptian, which dated from the 1903 season.

It is thus seen that the acidity of raw sugars varies within wide limits, and this is, of course, due to the methods of manufacture used. It is entirely within the manufacturer's power to make his sugar more or less acid, so that when it is known what degree of acidity or alkalinity is best to prevent deterioration, sugars can be made accordingly.

Only a large amount of data, however, will determine the relation between acidity and deterioration of cane sugar; and, although the method and results here given only attain a moderate degree of accuracy, yet they may be of reliable service in accumulating these data.

CHAPTER VIII.

Notes on Sour Cane.

The working of fermented cane is a subject upon which very little information is obtainable, and this is no doubt due no less to the great difficulty of the problem than to the fact that in most cane-growing countries frozen cane trouble seldom presents itself.

As soon as cane is frozen it is at the mercy of the multitude of bacteria which prey upon saccharine liquids. The fermentation may set in sooner or later, and be more or less severe, according to the severity of the freeze, and the weather after the freeze. Most bacteria work very slowly if at all at temperatures below 50° F., so that prolonged cold weather stays the fermentation until more favorable conditions set in. Warmth and moisture are both very favorable to bacterial action, and so hasten the deterioration of the cane.

There are several kinds of bacteria in all soils which could accomplish the destruction of the cane-sucrose with success, and there is no doubt that several species share the work of fermentation under most circumstances. But the most feared action

in Louisiana is what is valled the *viscous* or *mucilaginous* fermentation. In this process, the cane sugar is converted into a gum, *Dextran*, and various other products, including *mannitol*. The bacteria concerned in this action (the *leuconostoc mesenteriodes* and others) are anaerobic; that is, they thrive best in absence of air, obtaining their oxygen by deoxidizing the substances in solution; in this way a reduction or de-oxidation of the coloring matters is brought about, and the juice becomes characteristically bleached. The same or other species of bacteria produce organic acids of several kinds, all of which contribute to the acidity or sourness of the juice.

Thus the fermented juice possesses the triple characteristic of being acid, gummy, and bleached in appearance.

All the changes brought about in the juice during the souring go to increase the difficulty of extracting sugar from the juice. The gums, acids, etc., are all formed from the sugar (and almost all from the sucrose) of the juice, so that we get in the first place a definite loss of sucrose, and consequent increase in purity. Then again the gum it not removed by the ordinary clarification process, but persists in the clarified juice, syrup, and molasses, making the working of the juice a matter of great difficulty. Thirdly, while the acids of fermentation, consisting mainly of acetic and lactic acids, can of course be neutralized by lime, they are not all removed from the juice because their lime salts are soluble. Both the gums and the lime salts are melassagenic in character, so that their presence in the syrup brings about a serious reduction in the amount of sugar that can be extracted therefrom.

It follows from this, that when fermentation has proceeded beyond a certain stage, the difficulty of working the juice, and the much decreased yield obtained, will make the economical extraction of sugar from the juice impossible. At just what point this happens is a hard matter to decide. It depends not only upon the degree of fermentation, but on its nature. When the fermentation is mainly acid it will be more easily noticeable than when much gum is present. The criteria by which we judge the degree of fermentation are thus not only the acidity, but also the gum content of the juice. A third factor is also of importance, and that is the purity. A juice which had an

initial purity of 84, say, could be worked at a much greater degree of fermentation than one of, say, 70 original purity.

It would thus be unwise to judge the suitability of cane for sugar-making entirely from the acidity. The initial acidity of canes varies so much, that it is impossible to say how much of the acidity of a fermented juice is due to fermentation and how much to natural acidity. Moreover, as has been said, a juice with, say, 3 cc. acidity might have had a high initial purity and so be now of, say, 70 purity, or it could have had a low purity at first, and now be too low for working. Taking *both* the purity and acidity into consideration, however, one should be able to get a good idea of the value of the cane for sugar-making purposes.

The determination of purity, a comparatively easy matter with sweet cane, is sometimes rendered very difficult by fermentation. This is due to the presence of gum, which is soluble and not removed by the lead acetate used in the analysis. Moreover, the specific rotation of dextran is more than three times that of cane-sugar, so that the single polarization of a gummy juice may be much higher than is justified by the sugar content. This inflated single polarization leads to very false purity values: apparent purities of 100 and over on fermented juices are often obtained, and these values of course are entirely worthless. To get the true "apparent purity" when the presence of much gum is suspected, one must therefore employ special methods to determine the polarization of the juice. The best method is to precipitate the gums by means of alcohol. One takes the normal weight of the juice, clarifies with lead subacetate solution in the usual way, and fills up to 100 with 50% alcohol. Or one can, as Pellet* recommends, take 50 ccs. juice, 5 cc. lead subacetate solution, and fill up to 100 cc. with 95% alcohol. In some cases this amount of alcohol is insufficient to precipitate all the gums and a larger proportion of alcohol must be added. The solution is then filtered and polarized in the usual way—the single polarization being now unaffected by the gums.

Gum in juices is usually estimated as "alcoholic precipitate." One hundred cc. is concentrated to about one-quarter of its bulk,

*Bull. Assoc. Chim., 29, 215.

and the concentrate poured into about 100 cc. 90% alcohol, slightly acidified with hydrochloric acid. After settling, the precipitate is filtered off, using a Grooch crucible, washed with alcohol, dried and weighed. This estimation is but rarely performed in sugar-house work, although it might be used to obtain a definite idea of the gum-content of the juice.

In conducting the analysis of juices from sour canes, it is advisable to keep in mind the fact that the bacteria are still more active in the juices than in the cane, and that in consequence of this very serious changes are liable to occur in the composition of some normal juices which are allowed to stand for some time before analysis, i. e., for example, in a continuous sampling method by which small samples taken at frequent intervals are mixed together, and the mixture analyzed every few hours. Unless formaldehyde or other antiseptic is added to the sample, the fermentation which takes place while the juice is standing in the sample-can is liable to produce serious errors.

We have seen that the acidity test, together with a purity test by the modified method if necessary will give us criteria upon which to judge the suitability or otherwise of the cane for grinding. Turning now to the treatment of sour juice itself, we have, unfortunately, no special method of clarification by which the gums, or even the acids produced may be entirely removed from the juice. Certain precepts, however, may be followed to enable us to reduce the evil to a minimum. Firstly, the mill and juice-tanks around it, should be kept scrupulously clean; the fermentation already begun in the cane may continue with much greater vigor in the juice, if unclean conditions prevail, and if the raw juice be allowed to stand any time before being to some extent sterilized by the clarification process. The value of formaldehyde as an antiseptic added (1 part in 5,000) to standing juices can hardly be overestimated.

The use of soda to neutralize the excessive acidity of sour juices has been well recommended. The acids formed by the fermentation give, with lime, salts which are for the most part soluble and present right through to the molasses. As the melassagenic power of such lime salts is greater than that of the corresponding sodium salts, there is an obvious advantage in neutralizing some of the excessive acidity with soda. Caustic soda

can be used, but the carbonate is cheaper, easier to handle and in other ways more desirable. Of course the necessary amount of lime for removing the impurities must be added, as soda has by no means the same purifying action as lime.

The difficulty in boiling and the stiffness of syrups, etc., from sour cane comes in large part from the presence of the gums produced by the fermentation. There is no known way of removing these gums; it is therefore all the more necessary to keep down fermentation as far as possible from the time the juice enters the sugar-house.

APPENDIX.

The following tables are necessary adjuncts of various chapters of the bulletin, but are placed here for convenience.

(Appendix to Chapter I.)

TABLE OF DRY SUBSTANCE FROM REFRACTIVE INDEX AT 28° C.*

Index.	Per Cent. Dry Substance.	Index.	Per Cent. Dry Substance.	Index.	Per Cent. Dry Substance.	Index.	Per Cent. Dry Substance.
		1.3390	4.70	1.3450	8.70	1.3510	12.65
		91	4.80	51	8.80	11	12.70
		92	4.85	52	8.85	12	12.75
		93	4.90	53	8.90	13	12.80
		94	5.00	54	9.00	14	12.85
1.3335	1.00	95	5.05	55	9.05	15	12.90
36	1.05	96	5.10	56	9.10	16	13.00
37	1.10	97	5.20	57	9.20	17	13.10
38	1.20	98	5.25	58	9.25	18	13.20
39	1.30	99	5.30	59	9.30	19	13.25
1.3340	1.35	1.3400	5.40	1.3460	9.40	1.3520	13.30
41	1.40	01	5.45	61	9.45	21	13.40
42	1.50	02	5.50	62	9.50	22	13.45
43	1.60	03	5.60	63	9.60	23	13.50
44	1.65	04	5.65	64	9.65	24	13.60
45	1.70	05	5.70	65	9.70	25	13.65
46	1.80	06	5.80	66	9.80	26	13.70
47	1.85	07	5.85	67	9.85	27	13.80
48	1.90	08	5.90	68	9.90	28	13.85
49	2.00	09	6.00	69	10.00	29	13.90
1.3350	2.05	1.3410	6.05	1,3470	10.05	1.3530	14.00
51	2.10	11	6.10	71	10.10	31	14.05
52	2.20	12	6.20	72	10.20	32	14.10
53	2.25	13	6.25	73	10.25	33	14.20
54	2.30	14	6.30	74	10.30	34	14.25
55	2.40	15	6.40	75	10.40	35	14.30
56	2.45	16	6.45	76	10.45	36	14.40
57	2.50	17	6.50	77	10.50	37	14.45
58	2.60	18	6.60	78	10.60	38	14.50
59	2.65	19	6.65	79	10.65	39	14.60

*Arranged by Peck from Geerligs' table.

(Appendix to Chapter I.)

TABLE OF DRY SUBSTANCE FROM REFRACTIVE INDEX AT 28° C.—*Continued.*

Index.	Per Cent. Dry Substance.	Index.	Per Cent. Dry Substance.	Index.	Per Cent. Dry Substance.	Index.	Per Cent. Dry Substance.
1.3360	2.70	1.3420	6.70	1.3480	10.70	1.3540	14.65
61	2.80	21	6.80	81	10.80	41	14.70
62	2.85	22	6.85	82	10.85	42	14.80
63	2.90	23	6.90	83	10.90	43	14.85
64	3.00	24	7.00	84	11.00	44	14.90
65	3.05	25	7.05	85	11.05	45	14.95
66	3.10	26	7.10	86	11.10	46	15.00
67	3.20	27	7.20	87	11.20	47	15.05
68	3.25	28	7.25	88	11.25	48	15.10
69	3.30	29	7.30	89	11.30	49	15.20
1.3370	3.40	1.3430	7.40	1.3490	11.40	1.3550	15.25
71	3.45	31	7.45	91	11.45	51	15.30
72	3.50	32	7.50	92	11.50	52	15.40
73	3.60	33	7.60	93	11.60	53	15.45
74	3.65	34	7.65	94	11.65	54	15.50
75	3.70	35	7.70	95	11.70	55	15.60
76	3.80	36	7.80	96	11.75	56	15.65
77	3.85	37	7.85	97	11.80	57	15.70
78	3.90	38	7.90	98	11.85	58	15.75
79	4.00	39	8.00	99	11.90	59	15.80
1.3380	4.05	1.3440	8.05	1.3500	12.00	1.3560	15.85
81	4.10	41	8.10	01	12.05	61	15.90
82	4.20	42	8.20	02	12.10	62	16.00
83	4.25	43	8.25	03	12.20	63	16.05
84	4.30	44	8.30	04	12.25	64	16.10
85	4.40	45	8.40	05	12.30	65	16.20
86	4.45	46	8.45	06	12.40	66	16.25
87	4.50	47	8.50	07	12.45	67	16.30
88	4.60	48	8.60	08	12.50	68	16.40
89	4.65	49	8.65	09	12.60	69	16.45
1.3570	16.50	1.3630	20.15	1.3690	23.70	1.3750	27.20
71	16.60	31	20.20	91	23.80	51	27.30
72	16.65	32	20.30	92	23.85	52	27.35
73	16.70	33	20.35	93	23.90	53	27.40
74	16.75	34	20.40	94	23.95	54	27.45
75	16.80	35	20.45	95	24.00	55	27.50
76	16.85	36	20.50	96	24.05	56	27.60
77	16.90	37	20.60	97	24.10	57	27.65
78	17.00	38	20.65	98	24.15	58	27.70
79	17.05	39	20.70	99	24.20	59	27.75
1.3580	17.10	1.3640	20.80	1.3700	24.30	1.3760	27.80
81	17.20	41	20.85	01	24.35	61	27.85
82	17.25	42	20.90	02	24.40	62	27.90
83	17.30	43	20.95	03	24.45	63	27.95
84	17.40	44	21.00	04	24.50	64	28.00
85	17.45	45	21.05	05	24.60	65	28.05
86	17.50	46	21.10	06	24.65	66	28.10
87	17.60	47	21.15	07	24.70	67	28.15
88	17.65	48	21.20	08	24.80	68	28.20
89	17.70	49	21.30	09	24.85	69	28.30
1.3590	17.75	1.3650	21.35	1.3710	24.90	1.3770	28.35
91	17.80	51	21.40	11	24.95	71	28.40
92	17.85	52	21.45	12	25.00	72	.45
93	17.90	53	21.50	13	25.05	73	28.50
94	18.00	54	21.60	14	25.10	74	28.60
95	18.05	55	21.65	15	25.15	75	28.65
96	18.10	56	21.70	16	25.20	76	28.70
97	18.15	57	21.80	17	25.30	77	28.75
98	18.20	58	21.85	18	25.35	78	28.80
99	18.30	59	21.90	19	25.40	79	28.85

(Appendix to Chapter I.)

TABLE OF DRY SUBSTANCE FROM REFRACTIVE INDEX AT 28° C.—*Continued.*

Index.	Per Cent. Dry Substance.	Index.	Per Cent. Dry Substance.	Index.	Per Cent. Dry Substance.	Index.	Per Cent. Dry Substance.
1,3600	18.35	1.3660	21.95	1.3720	25.45	1.3780	28.90
01	18.40	61	22.00	21	25.50	81	28.95
02	18.45	62	22.05	22	25.60	82	29.00
03	18.50	63	22.10	23	25.65	83	29.05
04	18.60	64	22.15	24	25.70	84	29.10
05	18.65	65	22.20	25	25.80	85	29.15
06	18.70	66	22.30	26	25.85	86	29.20
07	18.80	67	22.35	27	25.90	87	29.30
08	18.85	68	22.40	28	25.95	88	29.35
09	18.90	69	22.45	29	26.00	89	29.40
1.3610	18.95	1.3670	22.50	1.3730	26.05	1.3790	29.45
11	19.00	71	22.60	31	26.10	91	29.50
12	19.05	72	22.65	32	26.15	92	29.60
13	19.10	73	22.70	33	26.20	93	29.65
14	19.20	74	22.80	34	26.30	94	29.70
15	19.25	75	22.85	35	26.35	95	29.75
16	19.30	76	22.90	36	26.40	96	29.80
17	19.40	77	22.95	37	26.45	97	29.85
18	19.45	78	23.00	38	26.50	98	29.90
19	19.50	79	23.05	39	26.60	99	29.95
1.3620	19.60	1.3680	23.10	1.3740	26.65	1.3800	30.00
21	19.65	81	23.15	41	26.70	01	30.05
22	19.70	82	23.20	42	26.80	02	30.10
23	19.75	83	23.30	43	26.85	03	30.15
24	19.80	84	23.35	44	26.90	04	30.20
25	19.85	85	23.40	45	26.95	05	30.30
26	19.90	86	23.45	46	27.00	06	30.35
27	20.00	87	23.50	47	27.05	07	30.40
28	20.05	88	23.60	48	27.10	08	30.45
29	20.10	89	23.65	49	27.15	09	30.50
1.3810	30.55	1.3870	33.90	1.3930	37.10	1.3990	40.30
11	30.60	71	33.95	31	37.15	91	40.35
12	30.65	72	34.00	32	37.20	92	40.40
13	30.70	73	34.05	33	27.25	93	40.45
14	30.80	74	34.10	34	37.30	94	40.50
15	30.85	75	34.15	35	37.35	95	40.60
16	30.90	76	34.20	36	37.40	96	40.65
17	30.95	77	34.30	37	37.45	97	40.70
18	31.00	78	34.35	38	37.50	98	40.75
19	31.05	79	34.40	39	37.60	99	40.80
1.3820	31.10	1.3880	34.45	1.3940	37.65	1.4000	40.85
21	31.15	81	34.50	41	37.70	01	40.90
22	31.20	82	34.55	42	37.75	02	40.95
23	31.30	83	34.60	43	37.80	03	41.00
24	31.35	84	34.65	44	37.85	04	41.05
25	31.40	85	34.70	45	37.90	05	41.10
26	31.45	86	34.80	46	37.95	06	41.15
27	31.50	87	34.85	47	38.00	07	41.20
28	31.55	88	34.90	48	38.05	08	41.25
29	31.60	89	34.95	49	38.10	09	41.30
1.3830	31.65	1.3890	35.00	1.3950	38.15	1.4010	41.35
31	31.70	91	35.05	51	38.20	11	41.40
32	31.80	92	35.10	52	38.25	12	41.45
33	31.85	93	35.15	53	38.30	13	41.50
34	31.90	94	35.20	54	38.35	14	41.55
35	31.95	95	35.25	55	38.40	15	41.60
36	32.00	96	35.30	56	38.45	16	41.65
37	32.05	97	35.35	57	38.50	17	41.70
38	32.10	98	35.40	58	38.60	18	41.75
39	32.15	99	35.45	59	38.65	19	41.80

(Appendix to Chapter I.)

TABLE OF DRY SUBSTANCE FROM REFRACTIVE INDEX AT 28° C.—*Continued.*

Index.	Per Cent. Dry Substance.	Index.	Per Cent. Dry Substance.	Index.	Per Cent. Dry Substance.	Index.	Per Cent. Dry Substance.
1.3840	32.20	1.3900	35.50	1.3960	38.70	1.4020	41.85
41	32.30	01	35.60	61	38.75	21	41.90
42	32.35	02	35.65	62	38.80	22	41.95
43	32.40	03	35.70	63	38.85	23	42.00
44	32.45	04	35.75	64	38.90	24	42.05
45	32.50	05	35.80	65	38.95	25	42.10
46	32.55	06	35.85	66	39.00	26	42.15
47	32.60	07	35.90	67	39.05	27	42.20
48	32.65	08	35.95	68	39.10	28	42.25
49	32.70	09	36.00	69	39.15	29	42.30
1.3850	32.80	1.3910	36.05	1.3970	39.20	1.4030	42.35
51	32.85	11	36.10	71	39.30	31	42.40
52	32.90	12	36.15	72	39.35	32	42.25
53	32.95	13	36.20	73	39.40	33	42.50
54	33.00	14	36.25	74	39.45	34	42.55
55	33.05	15	36.30	75	39.50	35	42.60
56	33.10	16	36.35	76	39.55	36	42.65
57	33.15	17	36.40	77	39.60	37	42.70
58	33.20	18	36.45	78	39.65	38	42.75
59	33.30	19	36.50	79	39.70	39	42.80
1.3860	33.35	1.3920	36.60	1.3980	39.80	1.4040	42.85
61	33.40	21	36.65	81	39.85	41	42.90
52	32.90	12	36.15	72	39.35	32	42.45
63	33.50	23	36.75	83	39.95	43	43.00
64	33.55	24	36.80	84	40.00	44	43.05
65	33.60	25	36.85	85	40.05	45	43.10
66	33.65	26	36.90	86	40.10	46	43.15
67	33.70	27	36.95	87	40.15	47	43.20
68	33.80	28	37.00	88	40.20	48	43.25
69	33.85	29	37.05	89	40.25	49	43.30
1.4050	43.35	1.4110	46.30	1.4170	49.20	1.4230	52.10
51	43.40	11	46.35	71	49.25	31	52.15
52	43.45	12	46.40	72	49.30	32	52.20
53	43.50	13	46.45	73	49.35	33	52.25
54	43.55	14	46.50	74	49.40	34	52.30
55	43.60	15	46.55	75	49.45	35	52.35
56	43.65	16	46.60	76	49.50	36	52.40
57	43.70	17	46.65	77	49.55	37	52.45
58	43.75	18	46.70	78	49.60	38	52.50
59	43.80	19	46.75	79	49.65	39	52.53
1.4060	43.85	1.4120	46.80	1.4180	49.70	1.4240	52.55
61	43.90	21	46.85	81	49.75	41	52.60
62	43.95	22	46.90	82	49.80	42	52.65
63	44.00	23	46.95	83	49.85	43	52.70
64	44.05	24	47.00	84	49.90	44	52.75
65	44.10	25	47.05	85	49.95	45	52.80
66	44.15	26	47.10	86	50.00	46	52.85
67	44.20	27	47.15	87	50.05	47	52.90
68	44.25	28	47.20	88	50.10	48	52.95
69	44.30	29	47.25	89	50.15	49	53.00
1.4070	44.35	1.4130	47.30	1.4190	50.20	1.4250	53.05
71	44.40	31	47.35	91	50.25	51	53.10
72	44.45	32	47.40	92	50.30	52	53.15
73	44.50	33	47.45	93	50.35	53	53.20
74	44.55	34	47.50	94	50.40	54	53.25
75	44.60	35	47.53	95	50.45	55	53.30
76	44.65	36	47.55	96	50.50	56	53.35
77	44.70	37	47.60	97	50.53	57	53.40
78	44.75	38	47.65	98	50.55	58	53.45
79	44.80	39	47.70	99	50.60	59	53.50

(Appendix to Chapter I.)

TABLE OF DRY SUBSTANCE FROM REFRACTIVE INDEX AT 28° C.—*Continued.*

Index.	Per Cent. Dry Substance.	Index.	Per Cent. Dry Substance.	Index.	Per Cent. Dry Substance.	Index.	Per Cent. Dry Substance.
1.4080	44.85	1.4140	47.75	1.4200	50.65	1.4260	53.53
81	44.90	41	47.80	01	50.70	61	53.55
82	44.95	42	47.85	02	50.75	62	53.60
83	45.00	43	47.90	03	50.80	63	53.65
84	45.05	44	47.95	04	50.85	64	53.70
85	45.10	45	48.00	05	50.90	65	53.75
86	45.15	46	48.05	06	50.95	66	53.80
87	45.20	47	48.10	07	51.00	67	53.85
88	45.25	48	48.15	08	51.05	68	53.90
89	45.30	49	48.20	09	51.10	69	53.95
1.4090	45.35	1.4150	48.25	1.4210	51.15	1.4270	54.00
91	45.40	51	48.30	11	51.20	71	54.05
92	45.45	52	48.35	12	51.25	72	54.10
93	45.50	53	48.40	13	51.30	73	54.15
94	45.53	54	48.45	14	51.35	74	54.20
95	45.55	55	48.50	15	51.40	75	54.23
96	45.60	56	48.53	16	51.45	76	54.25
97	45.65	57	48.55	17	51.50	77	54.30
98	45.70	58	48.60	18	51.53	78	54.35
99	45.75	59	48.65	19	51.55	79	54.40
1.4100	45.80	1.4160	48.70	1.4220	51.60	1.4280	54.45
01	45.85	61	48.75	21	51.65	81	54.50
02	45.90	62	48.80	22	51.70	82	54.55
03	45.95	63	48.85	23	51.75	83	54.60
04	46.00	64	48.90	24	51.80	84	54.65
05	46.05	65	48.95	25	51.85	85	54.70
06	46.10	66	49.00	26	51.90	86	54.73
07	46.15	67	49.05	27	51.95	87	54.75
08	46.20	68	49.10	28	52.00	88	54.80
09	46.25	69	49.15	29	52.05	89	54.85
1.4290	54.90	1.4350	57.60	1.4410	60.23	1.4470	62.83
91	54.95	51	57.65	11	60.25	71	62.85
92	55.00	52	57.70	12	60.30	72	62.90
93	55.05	53	57.73	13	60.35	73	62.95
94	55.10	54	57.75	14	60.40	74	63.00
95	55.15	55	57.80	15	60.45	75	63.05
96	55.20	56	57.85	16	60.50	76	63.10
97	55.23	57	57.90	17	60.53	77	63.15
98	55.25	58	57.95	18	60.55	78	63.20
99	55.30	59	58.00	19	60.60	79	63.23
1.4300	55.35	1.4360	58.05	1.4420	60.65	1.4480	63.25
01	55.40	61	58.10	21	60.70	81	63.30
02	55.45	62	58.15	22	60.75	82	63.35
03	55.50	63	58.20	23	60.80	83	63.40
04	55.55	64	58.23	24	60.83	84	63.45
05	55.60	65	58.25	25	60.85	85	63.50
06	55.65	66	58.30	26	60.90	86	63.53
07	55.70	67	58.35	27	60.95	87	63.55
08	55.73	68	58.40	28	61.00	88	63.60
09	55.75	69	58.45	29	61.05	89	63.65
1.4310	55.80	1.4370	58.50	1.4430	61.10	1.4490	63.70
11	55.85	71	58.53	31	61.15	91	63.75
12	55.90	72	58.55	32	61.20	92	63.80
13	55.95	73	58.60	33	61.23	93	63.83
14	56.00	74	58.65	34	61.25	94	63.85
15	56.05	75	58.70	35	61.30	95	63.90
16	56.10	76	58.75	36	61.35	96	63.95
17	56.15	77	58.80	37	61.40	97	64.00
18	56.20	78	58.83	38	61.45	98	64.05
19	56.23	79	58.85	39	61.50	99	64.10

(Appendix to Chapter I.)

TABLE OF DRY SUBSTANCE FROM REFRACTIVE INDEX AT 28° C.—*Continued.*

Index.	Per Cent. Dry Substance.	Index.	Per Cent. Dry Substance.	Index.	Per Cent. Dry Substance.	Index.	Per Cent. Dry Substance.
1.4320	56.25	1.4380	58.90	1.4440	61.53	1.4500	64.15
21	56.30	81	58.95	41	61.58	01	64.20
22	56.35	82	59.00	42	61.60	02	64.23
23	56.40	83	59.05	43	61.65	03	64.25
24	56.45	84	59.10	44	61.70	04	64.30
25	56.50	85	59.15	45	61.75	05	64.35
26	56.53	86	59.20	46	61.80	06	64.40
27	56.55	87	59.23	47	61.83	07	64.45
28	56.60	88	59.25	48	61.85	08	64.50
29	56.65	89	59.30	49	61.90	09	64.53
1.4330	56.70	1.4390	59.35	1.4450	61.95	1.4510	64.55
31	56.75	91	59.40	51	62.00	11	64.60
32	56.80	92	59.45	52	62.05	12	64.65
33	56.83	93	59.50	53	62.10	13	64.70
34	56.85	94	59.53	54	62.15	14	64.75
35	59.90	95	59.55	55	62.20	15	64.80
36	56.95	96	59.60	56	62.23	16	64.83
37	57.00	97	59.65	57	62.25	17	64.85
38	57.05	98	59.70	58	62.30	18	64.90
39	57.10	99	59.75	59	62.35	19	64.95
1.4340	57.15	1.4400	59.80	1.4460	62.40	1.4520	65.00
41	57.20	01	59.83	61	62.45	21	65.05
42	57.23	02	59.85	62	62.50	22	65.10
43	57.25	03	59.90	63	62.53	23	65.15
44	57.30	04	59.95	64	62.55	24	65.20
45	57.35	05	60.00	65	62.60	25	65.23
46	57.40	06	60.05	66	62.65	26	65.25
47	57.45	07	60.10	67	62.70	27	65.30
48	57.50	08	60.15	68	62.75	28	65.35
49	57.55	09	60.20	69	62.80	29	65.40
1.4530	65.45	1.4590	67.95	1.4650	70.45	1.4710	72.95
31	65.50	91	68.00	51	70.50	11	73.00
32	65.53	92	68.05	52	70.55	12	73.03
33	65.55	93	68.10	53	70.60	13	73.05
34	65.60	94	68.15	54	70.63	14	73.10
35	65.65	95	68.20	55	70.65	15	73.15
36	65.70	96	68.23	56	70.70	16	73.20
37	65.75	97	68.25	57	70.75	17	73.23
38	65.80	98	68.30	58	70.80	18	73.25
39	65.83	99	68.35	59	70.83	19	73.30
1.4540	65.85	1.4600	68.40	1.4660	70.85	1.4720	73.35
41	65.90	01	68.43	61	70.90	21	73.40
42	65.95	02	68.45	62	70.95	22	73.43
43	66.00	03	68.50	63	71.00	23	73.45
44	66.05	04	68.55	64	71.05	24	73.50
45	66.10	05	68.60	65	71.10	25	73.55
46	66.15	06	68.63	66	71.15	26	73.60
47	66.20	07	68.65	67	71.20	27	73.63
48	66.23	08	68.70	68	71.23	28	73.65
49	66.25	09	68.75	69	71.25	29	73.70
1.4550	66.30	1.4610	68.80	1.4670	71.30	1.4730	73.75
51	66.35	11	68.83	71	71.35	31	73.80
52	66.40	12	68.85	72	71.40	32	73.83
53	66.30	13	68.90	73	71.43	33	73.85
54	66.45	14	68.95	74	71.45	34	73.90
55	66.50	15	69.00	75	71.50	35	73.95
56	66.55	16	69.05	76	71.55	36	74.00
57	66.60	17	69.10	77	71.60	37	74.03
58	66.63	18	69.15	78	71.63	38	74.05
59	66.65	19	69.20	79	71.65	39	74.10

(Appendix to Chapter I.)

TABLE OF DRY SUBSTANCE FROM REFRACTIVE INDEX AT 28° C.—*Continued.*

Index.	Per Cent. Dry Substance.	Index.	Per Cent. Dry Substance.	Index.	Per Cent. Dry Substance.	Index.	Per Cent. Dry Substance.
1.4560	66.70	1.4620	69.23	1.4680	71.70	1.4740	74.15
61	66.75	21	69.25	81	71.75	41	74.20
62	66.80	22	69.30	82	71.80	42	74.23
63	66.83	23	69.35	83	71.83	43	74.25
64	66.85	24	69.40	84	71.85	44	74.30
65	66.90	25	69.43	85	71.90	45	74.35
66	66.95	26	69.45	86	71.95	46	74.40
67	67.00	27	69.50	87	72.00	47	74.43
68	67.05	28	69.55	88	72.05	48	74.45
69	67.10	29	69.60	89	72.10	49	74.50
1.4570	67.15	1.4630	69.63	1.4690	72.15	1.4750	74.55
71	67.20	31	69.65	91	72.20	51	74.60
72	67.23	32	69.70	92	72.23	52	74.63
73	67.25	33	69.75	93	72.25	53	74.65
74	67.30	34	69.80	94	72.30	54	74.70
75	67.35	35	69.83	95	72.35	55	74.75
76	67.40	36	69.85	96	72.40	56	74.80
77	67.43	37	69.90	97	72.43	57	74.83
78	67.45	38	69.95	98	72.45	58	74.85
79	67.50	39	70.00	99	72.50	59	74.90
1.4580	67.55	1.4640	70.05	1.4700	72.55	1.4760	74.95
81	67.60	41	70.10	01	72.60	61	75.00
82	67.63	42	70.15	02	72.63	62	75.03
83	67.65	43	70.20	03	72.65	63	75.05
84	67.70	44	70.23	04	72.70	64	75.10
85	67.75	45	70.25	05	72.75	65	75.15
86	67.80	46	70.30	06	72.80	66	75.20
87	67.83	47	70.35	07	72.83	67	75.23
88	67.85	48	70.40	08	72.85	68	75.25
89	67.90	49	70.43	09	72.90	69	75.30
1.4770	75.35	1.4830	77.75	1.4890	80.05	1.4950	82.40
71	75.40	31	77.80	91	80.10	51	82.43
72	75.43	32	77.83	92	80.15	52	82.45
73	75.45	33	77.85	93	80.20	53	82.50
74	70.50	34	77.90	94	80.23	54	82.53
75	75.55	35	77.95	95	80.25	55	82.55
76	75.60	36	78.00	96	80.30	56	82.60
77	75.63	37	78.03	97	80.35	57	82.63
78	75.65	38	78.05	98	80.40	58	82.65
79	75.70	39	78.10	99	80.43	59	82.70
1.4780	75.75	1.4840	78.15	1.4900	80.45	1.4960	82.75
81	75.80	41	78.20	01	80.50	61	82.80
82	75.83	42	78.23	02	80.53	62	82.83
83	75.85	43	78.25	03	80.55	63	82.85
84	75.90	44	78.30	04	80.60	64	82.90
85	75.95	45	78.35	05	80.63	65	82.95
86	76.00	46	78.40	06	80.65	66	83.00
87	76.03	47	78.43	07	80.70	67	83.03
88	76.05	48	78.45	08	80.75	68	83.05
89	76.10	49	78.50	09	80.80	69	83.10
1.4790	76.15	1.4850	78.53	1.4910	80.83	1.4970	83.15
91	76.20	51	78.55	11	80.85	71	83.20
92	76.23	52	78.60	12	80.90	72	83.23
93	76.25	53	78.63	13	80.95	73	83.25
94	76.30	54	78.65	14	81.00	74	83.30
95	76.35	55	78.70	15	81.03	75	83.35
96	76.40	56	78.75	16	81.05	76	83.40
97	76.43	57	78.80	17	81.10	77	83.43
98	76.45	58	78.83	18	81.15	78	83.45
99	76.50	59	78.85	19	81.20	79	83.50

(Appendix to Chapter I.)

TABLE OF DRY SUBSTANCE FROM REFRACTIVE INDEX AT 28° C.—*Continued.*

Index.	Per Cent. Dry Substance.	Index.	Per Cent. Dry Substance.	Index.	Per Cent. Dry Substance.	Index.	Per Cent. Dry Substance.
1.4800	76.55	1.4860	78.90	1.4920	81.23	1.4980	83.53
01	76.60	61	78.95	21	81.25	81	83.55
02	76.63	62	79.00	22	81.30	82	83.60
03	76.65	63	79.03	23	81.35	83	83.63
04	76.70	64	79.05	24	81.40	84	83.65
05	76.75	65	79.10	25	81.43	85	83.70
06	76.80	66	79.15	26	81.45	86	83.75
07	76.83	67	79.20	27	81.50	87	83.80
08	76.85	68	79.28	28	81.53	88	83.83
09	76.90	69	79.25	29	81.55	89	83.85
1.4810	76.95	1.4870	79.30	1.4930	81.60	1.4990	83.90
11	77.00	71	79.35	31	81.63	91	83.95
12	77.03	72	79.40	32	81.65	92	84.00
13	77.05	73	79.43	33	81.70	93	84.03
14	77.10	74	79.45	34	81.75	94	84.05
15	77.15	75	79.50	35	81.80	95	84.10
16	77.20	76	79.53	36	81.83	96	84.15
17	77.23	77	79.55	37	81.85	97	84.20
18	77.25	78	79.60	38	81.90	98	84.23
19	77.30	79	79.63	39	81.95	99	84.25
1.4820	77.35	1.4880	79.65	1.4940	82.00	1.5000	84.30
21	77.40	81	79.70	41	82.03	01	84.33
22	77.43	82	79.75	42	82.05	02	84.35
33	77.45	83	79.80	43	82.10	03	84.40
24	77.50	84	79.83	44	82.15	04	84.45
25	77.55	85	79.85	45	82.20	05	84.50
26	77.60	86	79.90	46	82.23	06	84.53
27	77.63	87	79.95	47	82.25	07	84.55
28	77.65	88	80.00	48	82.30	08	84.60
29	77.70	89	80.03	49	82.35	09	84.63
1.5010	84.65	1.5070	86.90	1.5130	89.10		
11	84.70	71	86.93	31	89.13		
12	84.75	72	86.95	32	89.15		
13	84.80	73	87.00	33	89.20		
14	84.83	74	87.03	34	89.23		
15	84.85	75	87.05	35	89.25		
16	84.90	76	87.10	36	89.30		
17	84.93	77	87.15	37	89.35		
18	84.95	78	87.20	38	89.40		
19	85.00	79	87.23	39	89.43		
1.5020	85.03	1.5080	87.25	1.5140	89.45		
21	85.05	81	87.30	41	89.50		
22	85.10	82	87.33	42	89.53		
23	85.15	83	87.35	43	89.55		
24	85.20	84	87.40	44	89.60		
25	85.23	85	87.45	45	89.63		
26	85.25	86	87.50	46	89.65		
27	85.30	87	87.53	47	89.70		
28	85.33	88	87.55	48	89.75		
29	85.35	89	87.60	49	89.80		
1.5030	85.40	1.5090	87.63	1.5150	89.83		
31	85.45	91	87.65	51	89.85		
32	85.50	92	87.70	52	89.90		
33	85.53	93	87.75	53	89.93		
34	85.55	94	87.80	54	89.95		
35	85.60	95	87.83	55	90.00		
36	85.63	96	87.85	56	90.03		
37	85.65	95	87.90	57	90.05		
38	85.70	98	87.93	58	90.10		
39	85.75	99	87.95	59	90.13		

(Appendix to Chapter I.)

TABLE OF DRY SUBSTANCE FROM REFRACTIVE INDEX AT 28° C.—*Continued.*

Index.	Per Cent. Dry Substance.	Index.	Per Cent. Dry Substance.	Index.	Per Cent. Dry Substance.	Index.	Per Cent. Dry Substance.
1.5040	85.80	1.5100	88.00	1.5160	90.15		
41	85.83	01	88.03	61	90.20		
42	85.85	02	88.05	62	90.25		
43	85.90	03	88.10	63	90.30		
44	85.93	04	88.15	64	90.33		
45	85.95	05	88.20	65	90.35		
46	86.00	06	88.23	66	90.40		
47	86.03	07	88.25	67	90.43		
48	86.05	08	88.30	68	90.45		
49	86.10	09	88.33	69	90.50		
1.5050	86.15	1.5110	88.35	1.5170	90.53		
51	86.20	11	88.40	71	90.55		
52	86.23	12	88.45	72	90.60		
53	86.25	13	88.50	73	90.63		
54	86.30	14	88.53	74	90.65		
55	86.33	15	88.55	75	90.70		
56	86.35	16	88.60	76	90.75		
57	86.40	17	88.63	77	90.80		
58	86.45	18	88.65	78	90.83		
59	86.50	19	88.70	79	90.85		
1.5060	86.53	1.5120	88.75	1.5180	90.90		
61	86.55	21	88.80	81	90.93		
62	86.60	22	88.83	82	90.95		
63	86.63	23	88.85				
64	86.65	24	88.90				
65	86.70	25	88.93				
66	86.75	26	88.95				
67	86.80	27	89.00				
68	86.83	28	89.03				
69	86.85	29	89.05				

(Appendix to Chapter I.)

TABLE II.

TABLE OF CORRECTIONS FOR THE TEMPERATURE.

DRY SUBSTANCE.

Temperature of the prisms °C.	0	5	10	15	20	25	30	40	50	60	70	80	90
						Subtract.							
20° C.	.53	.54	.55	.56	.57	.58	.60	.62	.64	.62	.61	.60	.58
21	.46	.47	.48	.49	.50	.51	.52	.54	.56	.54	.53	.52	.50
22	.40	.41	.42	.42	.43	.44	.45	.47	.48	.47	.46	.45	.44
23	.33	.33	.34	.35	.36	.37	.38	.39	.40	.39	.38	.38	.38
24	.26	.26	.27	.28	.28	.29	.30	.31	.32	.31	.31	.30	.30
25	.20	.20	.21	.21	.22	.22	.23	.23	.24	.23	.23	.23	.22
26	.12	.12	.13	.14	.14	.14	.15	.15	.16	.16	.16	.15	.14
27	.07	.07	.07	.07	.07	.07	.08	.08	.08	.08	.08	.08	.07
						Add.							
29° C.	.07	.07	.07	.07	.07	.07	.08	.08	.08	.08	.08	.08	.07
30	.12	.12	.13	.14	.14	.14	.15	.15	.16	.16	.16	.15	.14
31	.20	.20	.21	.21	.22	.22	.23	.23	.24	.23	.23	.23	.22
32	.26	.26	.27	.28	.28	.29	.30	.31	.32	.31	.31	.30	.30
33	.33	.33	.34	.35	.36	.37	.38	.39	.40	.39	.38	.38	.38
34	.40	.41	.42	.42	.43	.44	.45	.47	.48	.47	.46	.45	.44
35	.46	.47	.48	.49	.50	.51	.52	.54	.56	.54	.53	.52	.50

(Appendix to Chapter I.)

TABLE III.

DETERMINATION OF DRY SUBSTANCE BY THE IMMERSION REFRACTOMETER.

Scale Reading	% Sugar	Sc. R.	% S.	Sc. R.	% S.	Sc. R.	% S.	Sc. R.	% S.	Sc. R.	% S.	Sc. R.	% S.
15,0	0,00	**23,0**	2,11	**31,0**	4,21	**39,0**	6,31	**47,0**	8,34	**55,0**	10,29	**63,0**	12,23
1	0,03	1	13	1	24	1	33	1	36	1	32	1	25
2	0,05	2	16	2	26	2	36	2	39	2	34	2	28
3	0,08	3	19	3	29	3	39	3	41	3	36	3	30
4	0,11	4	21	4	32	4	41	4	44	4	39	4	32
5	0,13	5	24	5	34	5	43	5	46	5	41	5	35
6	0,16	6	26	6	37	6	46	6	49	6	44	6	37
7	0,19	7	29	7	39	7	49	7	51	7	46	7	39
8	0,21	8	32	8	42	8	51	8	53	8	49	8	42
9	0,24	9	34	9	45	9	54	9	56	9	51	9	44
16,0	0,26	**24,0**	37	**32,0**	48	**40,0**	56	**48,0**	58	**56,0**	53	**64,0**	46
1	0,29	1	40	1	50	1	59	1	60	1	56	1	49
2	0,32	2	42	2	53	2	61	2	63	2	58	2	51
3	0,34	3	45	3	56	3	64	3	66	3	60	3	53
4	0,37	4	48	4	58	4	66	4	68	4	63	4	56
5	0,40	5	50	5	61	5	69	5	70	5	66	5	58
6	0,42	6	53	6	64	6	72	6	73	6	68	6	60
7	0,45	7	56	7	66	7	74	7	75	7	70	7	63
8	0.48	8	58	8	69	8	77	8	78	8	73	8	65
9	0,50	9	61	9	71	9	79	9	80	9	75	9	67
17,0	0,53	**25,0**	64	**33,0**	74	**41,0**	82	**49,0**	83	**57,0**	78	**65,0**	69
1	0,56	1	66	1	77	1	84	1	85	1	80	1	72
2	0,58	2	69	2	79	2	87	2	88	2	83	2	74
3	0,61	3	71	3	82	3	90	3	90	3	85	3	76
4	0,64	4	74	4	84	4	92	4	92	4	88	4	79
5	0,66	5	77	5	87	5	95	5	95	5	90	5	81
6	0,69	6	79	6	90	6	97	6	97	6	92	6	83
7	0,71	7	82	7	92	7	7,00	7	9,00	7	95	7	86
8	0,74	8	84	8	95	8	03	8	03	8	97	8	88
9	0,77	9	87	9	98	9	05	9	05	9	11,00	9	90
18,0	0,79	**26,0**	90	**34,0**	5,00	**42,0**	08	**50,0**	07	**58,0**	03	**66,0**	93
1	0,82	1	92	1	03	1	10	1	10	1	05	1	95
2	0,84	2	95	2	05	2	13	2	12	2	07	2	97
3	0,87	3	98	3	08	3	15	3	15	3	10	3	13,00
4	0,90	4	3,00	4	11	4	18	4	17	4	12	4	03
5	0,92	5	03	5	13	5	20	5	19	5	15	5	05
6	0,95	6	05	6	16	6	23	6	22	6	17	6	07
7	0,98	7	08	7	19	7	26	7	24	7	19	7	09
8	1,00	8	11	8	21	8	28	8	27	8	22	8	11
9	03	9	13	9	24	9	31	9	29	9	24	9	14
19,0	05	**27,0**	16	**35,0**	26	**43,0**	33	**51,0**	32	**59,0**	27	**67,0**	16
1	08	1	19	1	29	1	36	1	34	1	29	1	18
2	11	2	21	2	32	2	39	2	36	2	32	2	20
3	13	3	24	3	34	3	41	3	39	3	34	3	23
4	16	4	26	4	37	4	43	4	41	4	36	4	25
5	19	5	29	5	40	5	46	5	44	5	39	5	27

(Appendix to Chapter I.)

TABLE III—Continued.

Scale Reading	% Sugar	Sc. R.	% S.	Sc. R.	% S.	Sc. R.	% S.	Sc. R.	% S.	Sc. R.	% S.	Sc. R.	% S.
6	21	6	32	6	42	6	49	6	46	6	41	6	29
7	24	7	34	7	45	7	51	7	49	7	44	7	32
8	26	8	37	8	48	8	54	8	51	8	46	8	34
9	29	9	40	9	50	9	56	9	53	9	49	9	36
20,0	32	28,0	42	36,0	53	44,0	59	52,0	56	60,0	51	68,0	38
1	34	1	45	1	56	1	61	1	58	1	53	1	40
2	37	2	48	2	58	2	64	2	60	2	56	2	43
3	40	3	50	3	61	3	66	3	63	3	58	3	45
4	42	4	53	4	64	4	69	4	66	4	60	4	48
5	45	5	56	5	66	5	72	5	68	5	63	5	50
6	48	6	58	6	69	6	74	6	70	6	66	6	52
7	50	7	61	7	71	7	77	7	73	7	68	7	54
8	53	8	64	8	74	8	79	8	75	8	70	8	57
9	56	9	66	9	77	9	82	9	78	9	73	9	59
21,0	58	29,0	69	37,0	79	45,0	84	53,0	80	61,0	75	69,0	61
1	61	1	71	1	82	1	87	1	83	1	78	1	63
2	64	2	74	2	84	2	90	2	85	2	80	2	66
3	66	3	77	3	87	3	92	3	88	3	83	3	68
4	69	4	79	4	90	4	95	4	90	4	85	4	70
5	71	5	82	5	92	5	97	5	92	5	88	5	73
6	74	6	84	6	95	6	8,00	6	95	6	90	6	75
7	77	7	87	7	98	7	03	7	97	7	92	7	77
8	79	8	90	8	6,00	8	95	8	10,00	8	95	8	79
9	82	9	92	9	03	9	07	9	03	9	97	9	82
22,0	84	30,0	95	38,0	05	46,0	10	54,0	05	62,0	12,00	70,0	84
1	87	1	98	1	08	1	12	1	07	1	03	1	87
2	90	2	4,00	2	10	2	15	2	10	2	05	2	89
3	92	3	03	3	13	3	17	3	12	3	07	3	92
4	95	4	05	4	15	4	19	4	15	4	09	4	94
5	98	5	08	5	17	5	22	5	17	5	12	5	96
6	2,00	6	11	6	20	6	24	6	19	6	14	6	98
7	03	7	13	7	23	7	27	7	22	7	16	7	14,00
8	05	8	16	8	26	8	29	8	24	8	18	8	03
9	08	9	19	9	28	9	92	9	27	9	21	9	05
71,0	14,07	76,0	15,20	81,0	16,31	86,0	17,44	91,0	18,53	96,0	19,59	101,0	20,66
1	09	1	22	1	33	1	47	1	55	1	61	1	68
2	11	2	24	2	35	2	49	2	57	2	63	2	70
3	14	3	26	3	38	3	51	3	59	3	66	3	72
4	16	4	28	4	40	4	53	4	61	4	68	4	74
5	18	5	30	5	42	5	55	5	63	5	70	5	76
6	20	6	32	6	44	6	58	6	66	6	72	6	78
7	23	7	34	7	47	7	60	7	68	7	74	7	80
8	25	8	36	8	49	8	62	8	70	8	76	8	82
9	27	9	38	9	51	9	64	9	72	9	78	9	85
72,0	29	77,0	40	82,0	54	87,0	66	92,0	74	97,0	80	102,0	87
1	32	1	42	1	56	1	68	1	76	1	82	1	89
2	34	2	44	2	59	2	71	2	78	2	85	2	91
3	36	3	47	3	61	3	73	3	80	3	87	3	93

(Appendix to Chapter I.)

TABLE III—Continued.

Scale Reading	% Sugar	Sc. R.	% S.	Sc. R.	% S.	Sc. R.	% S.	Sc. R.	% S.	Sc. R.	% S.	Sc. R.	% S.
4	38	4	49	4	63	4	75	4	82	4	89	4	95
5	40	5	51	5	65	5	77	5	85	5	91	5	97
6	43	6	54	6	68	6	79	6	87	6	93	6	21,00
7	45	7	56	7	70	7	82	7	89	7	95	7	02
8	48	8	59	8	72	8	84	8	91	8	97	8	04
9	50	9	61	9	74	9	86	9	93	9	20,00	9	06
73,0	52	78,0	63	83,0	76	88,0	89	93,0	95	98,0	02	103,0	08
1	54	1	65	1	79	1	91	1	97	1	04	1	10
2	57	2	68	2	81	2	93	2	19,00	2	06	2	13
3	59	3	70	3	83	3	95	3	02	3	08	3	15
4	61	4	72	4	85	4	98	4	04	4	10	4	17
5	63	5	74	5	88	5	18,00	5	06	5	13	5	19
6	66	6	76	6	90	6	02	6	08	6	15	6	21
7	68	7	79	7	92	7	04	7	10	7	17	7	23
8	70	8	81	8	95	8	06	8	13	8	19	8	25
9	73	9	83	9	97	9	08	9	15	9	21	9	27
74,0	75	79,0	85	84,0	17,00	89,0	10	94,0	17	99,0	23	104,0	29
1	77	1	88	1	02	1	13	1	19	1	25	1	31
2	79	2	90	2	04	2	15	2	21	2	27	2	34
3	82	3	92	3	07	3	17	3	23	3	29	3	36
4	84	4	95	4	09	4	19	4	25	4	31	4	38
5	87	5	97	5	11	5	21	5	27	5	34	5	40
6	89	6	16,00	6	13	6	23	6	29	6	36	6	42
7	92	7	03	7	15	7	25	7	31	7	38	7	44
8	94	8	05	8	18	8	27	8	34	8	40	8	47
9	96	9	07	9	20	9	29	9	36	9	42	9	49
75,0	98	80,0	09	85,0	22	90,0	31	95,0	38	100,0	44	105,0	51
1	15,00	1	11	1	24	1	34	1	40	1	47	1	53
2	03	2	13	2	27	2	36	2	42	2	49	2	55
3	05	3	16	3	29	3	38	3	44	3	51	3	57
4	07	4	18	4	31	4	40	4	47	4	53	4	59
5	09	5	20	5	33	5	42	5	49	5	55	5	61
6	11	6	22	6	35	6	44	6	51	6	57	6	63
7	13	7	24	7	38	7	47	7	53	7	59	7	66
8	16	8	27	8	40	8	49	8	55	8	61	8	68
9	18	9	29	9	42	9	51	9	57	9	63	9	70
												106,0	21,71

(Appendix to Chapter I.)

TABLE IV.

TEMPERATURE CORRECTION TABLE FOR READINGS OF IMMERSION REFRACTOMETER.

(Stanek.)

Temp. °C.	Refrac. Reading 13-17	17-19	19-26	26-34	34-42	42-50	50-58	58-66	66-76	76-84	84-92	92-96	Temp. °C.
	Corrections to be subtracted from the refractometer reading.												
12	1.00	1.00	1.05	1.10	1.20	1.25	1.30	1.35	1.45	1.50	1.50	1.55	12
13	0.85	0.85	0.90	0.95	1.00	1.00	1.10	1.10	1.20	1.20	1.25	1.30	13
14	0.70	0.70	0.70	0.75	0.75	0.80	0.85	0.85	0.95	0.95	1.00	1.00	14
15	0.50	0.50	0.50	0.55	0.55	0.55	0.60	0.60	0.70	0.70	0.70	0.75	15
16	0.30	0.30	0.30	0.35	0.35	0.35	0.35	0.40	0.45	0.45	0.40	0.40	16
17	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.15	0.15	0.15	0.15	0.15	17
	Corrections to be added to the refractometer reading.												
18	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.15	0.15	0.15	0.15	0.15	18
19	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.40	0.45	0.45	0.50	0.55	19
20	0.55	0.55	0.55	0.60	0.60	0.65	0.65	0.70	0.75	0.75	0.80	0.80	20
21	0.80	0.80	0.80	0.80	0.80	0.90	0.95	1.00	1.10	1.10	1.10	1.20	21
22	1.05	1.05	1.10	1.10	1.10	1.20	1.25	1.30	1.40	1.40	1.45	1.55	22
23	1.30	1.35	1.40	1.40	1.40	1.50	1.55	1.60	1.70	1.70	1.80	1.90	23
24	1.60	1.60	1.65	1.70	1.70	1.80	1.85	1.90	2.00	2.05	2.15	2.25	24
25	1.85	1.85	1.90	2.00	2.00	2.10	2.20	2.35	2.35	2.40	2.50	2.60	25
26	2.10	2.15	2.20	2.30	2.30	2.45	2.50	2.65	2.70	2.75	2.90	3.00	26
27	2.40	2.45	2.50	2.60	2.65	2.70	2.85	2.95	3.00	3.10	3.30	3.45	27
28	2.70	2.75	2.80	2.90	3.00	3.05	3.20	3.25	3.35	3.45	3.65	3.85	28
29	3.00	3.05	3.10	3.25	3.30	3.40	3.55	3.60	3.70	3.85	4.05	4.30	29
30	3.30	3.40	3.45	3.60	3.65	3.75	3.90	4.00	4.10	4.25	4.50	4.70	30

(Appendix to Chapter II.)

TABLE V.

SUCROSE TABLE.*

(Dry Lead Method.)

Brix (uncorrected).

Pol.		1	2	3	4	5	6	7	8	9	10
1		0.26	0.26	0.26	0.26	0.26	0.25	0.25	0.25	0.25	0.25
2		0.52	0.52	0.51	0.51	0.51	0.51	0.51	0.50	0.50	0.50
3		0.78	0.77	0.77	0.77	0.76	0.76	0.76	0.76	0.75	0.75
4			1.03	1.03	1.02	1.02	1.02	1.01	1.01	1.00	1.00
5			1.29	1.28	1.28	1.27	1.27	1.26	1.26	1.25	1.25
6			1.55	1.54	1.53	1.53	1.52	1.52	1.51	1.50	1.50
7			1.80	1.80	1.79	1.78	1.78	1.77	1.76	1.75	1.75
8				2.05	2.05	2.04	2.03	2.02	2.01	2.01	2.00
9				2.31	2.30	2.29	2.28	2.27	2.27	2.26	2.25
10				2.57	2.56	2.55	2.54	2.53	2.52	2.51	2.50
11				2.82	2.81	2.80	2.79	2.78	2.77	2.76	2.75
12					3.07	3.06	3.04	3.03	3.02	3.01	3.00
13					3.32	3.31	3.30	3.29	3.27	3.26	3.25
14					3.58	3.57	3.55	3.54	3.52	3.51	3.50
15					3.84	3.82	3.81	3.79	3.78	3.76	3.75
16	Tenths					4.08	4.06	4.04	4.03	4.01	4.00
17	of a					4.33	4.31	4.30	4.28	4.26	4.25
18	division	% Sucrose				4.59	4.57	4.55	4.53	4.51	4.50
19	0.1	0.03				4.84	4.82	4.80	4.78	4.77	4.75
20	0.2	0.05					5.08	5.06	5.04	5.02	5.00
21	0.3	0.08					5.33	5.31	5.29	5.27	5.25
22	0.4	0.10					5.58	5.56	5.54	5.52	5.50
23	0.5	0.13					5.84	5.81	5.79	5.77	5.75
24	0.6	0.15						6.07	6.04	6.02	6.00
25	0.7	0.18						6.32	6.30	6.27	6.25
	0.8	0.20									
	0.9	0.23									

*See also table in Chap. II.

(Appendix to Chapter III.)

TABLE VI.

RECIPROCALS OF NUMBERS FROM 11 TO 36, ADVANCING BY TENTHS.

Number	Reciprocal	Number	Reciprocal	Number	Reciprocal	Number	Reciprocal	Number	Reciprocal
11.0	.0909	**16.0**	.0625	**21.0**	.0476	**26.0**	.0385	**31.0**	.0322
11.1	.0900	16.1	.0621	21.1	.0474	26.1	.0383	31.1	0.321
11.2	.0893	16.2	.0617	21.2	.0472	26.2	.0381	31.2	.0320
11.3	.0885	16.3	.0613	21.3	.0469	26.3	.0380	31.3	.0319
11.4	.0877	16.4	.0610	21.4	.0467	26.4	.0379	31.4	.0318
11.5	.0869	16.5	.0606	21.5	.0465	26.5	.0377	31.5	.0317
11.6	.0862	16.6	.0602	21.6	.0463	26.6	.0376	31.6	.0316
11.7	.0855	16.7	.0599	21.7	.0461	26.7	.0374	31.7	.0315
11.8	.0847	16.8	.0595	21.8	.0459	26.8	.0373	31.8	.0314
11.9	.0840	16.9	.0592	21.9	.0457	26.9	.0372	31.9	.0313
12.0	.0383	**17.0**	.0588	**22.0**	.0454	**27.0**	.0370	**32.0**	.0312
12.1	.0826	17.1	.0585	22.1	.0452	27.1	.0369	32.1	.0311
12.2	.0820	17.2	.0581	22.2	.0450	27.2	.0368	32.2	.0310
12.3	.0813	17.3	.0578	22.3	.0448	27.3	.0366	32.3	.0309
12.4	.0806	17.4	.0575	22.4	.0446	27.4	.0365	32.4	.0308
12.5	.0800	17.5	.0571	22.5	.0444	27.5	0.364	32.5	.0308
12.6	.0794	17.6	.0568	22.6	.0442	27.6	.0362	32.6	.0307
12.7	.0787	17.7	.0565	22.7	.0440	27.7	.0361	32.7	.0305
12.8	.0781	17.8	.0562	22.8	.0438	27.8	.0360	32.8	.0305
12.9	.0775	17.9	.0559	22.9	.0437	27.9	.0358	32.9	.0304
13.0	.0769	**18.0**	.0555	**23.0**	.0435	**28.0**	.0357	**33.0**	.0303
13.1	.0763	18.1	.0552	23.1	.0432	28.1	.0356	33.1	.0302
13.2	.0757	18.2	.0549	23.2	.0431	28.2	.0355	33.2	.0301
13.3	.0752	18.3	.0546	23.3	.0429	28.3	.0353	33.3	.0300
13.4	.0746	18.4	.0543	23.4	.0427	28.4	.0352	33.4	.0299
13.5	.0741	18.5	.0540	23.5	.0425	28.5	.0351	33.5	.0298
13.6	.0735	18.6	.0538	23.6	.0424	28.6	.0350	33.6	.0297
13.7	.0730	18.7	.0535	23.7	.0422	28.7	.0348	33.7	.0296
13.8	.0725	18.8	.0532	23.8	.0420	28.8	.0347	33.8	0.295
13.9	.0719	18.9	.0529	23.9	.0418	28.9	.0346	33.9	.0295
14.0	.0714	**19.0**	.0526	**24.0**	.0417	**29.0**	.0345	**34.0**	.0294
14.1	0.709	19.1	.0523	24.1	.0415	29.1	.0344	34.1	.0293
14.2	.0704	19.2	.0521	24.2	.0413	29.2	.0342	34.2	.0292
14.3	.0699	19.3	.0518	24.3	.0411	29.3	.0341	34.3	.0291
14.4	.0694	19.4	.0515	24.4	.0409	29.4	.0340	34.4	.0290
14.5	.0690	19.5	.0513	24.5	.0408	29.5	.0339	34.5	.0289
14.6	.0685	19.6	.0510	24.6	.0406	29.6	.0338	34.6	.0289
14.7	0.680	19.7	.0508	24.7	.0405	29.7	.0337	34.7	.0288
14.8	.0676	19.8	.0505	24.8	.0403	29.8	.0335	34.8	.0287
14.9	.0671	19.9	.0502	24.9	.0402	29.9	.0334	34.9	.0286

(Appendix to Chapter III.)

TABLE VI —Continued.

Number	Reciprocal	Number	Reciprocal	Number	Reciprocal	Number	Reciprocal	Number	Reciprocal
15.0	.0667	**20.0**	.0500	**25.0**	.0400	**30.0**	.0333	**35.0**	.0285
15.1	.0662	20.1	.0497	25.1	.0398	30.1	.0332	35.1	.0284
15.2	.0658	20.2	.0495	25.2	.0397	30.2	.0331	35.2	.0284
15.3	.0654	20.3	.0493	25.3	.0395	30.3	.0330	35.3	.0283
15.4	.0649	20.4	.0490	25.4	.0394	30.4	.0329	35.4	.0282
15.5	.0645	20.5	.0488	25.5	.0392	30.5	.0328	35.5	.0282
15.6	.0641	20.6	.0485	25.6	.0391	30.6	.0327	35.6	.0281
15.7	.0637	20.7	.0483	25.7	.0389	30.7	.0326	35.7	.0280
15.8	.0633	20.8	.0481	25.8	.0388	30.8	.0325	35.8	.0279
15.9	.0629	20.9	.0478	25.9	.0386	30.9	.0324	35.9	.0278

(Appendix to Chapter IV.)

TABLE VII.

Table of Factors for Clerget Determination $\frac{(a - b)\ 100}{144 - 1/2\ T}$

(W. B. Taggart.*)

Degrees Centigrate	Tenths of a Degree									
	0	1	2	3	4	5	6	7	8	9
15.....	0.7326	0.7328	0.7331	0.7334	0.7336	0.7339	0.7342	0.7344	0.7347	0.7350
16.....	0.7352	0.7355	0.7358	0.7361	0.7363	0.7366	0.7369	0.7371	0.7374	0.7377
17.....	0.7380	0.7382	0.7385	0.7388	0.7391	0.7393	0.7396	0.7399	0.7401	0.7404
18.....	0.7407	0.7410	0.7412	0.7415	0.7418	0.7421	0.7423	0.7426	0.7429	0.7432
19.....	0.7434	0.7437	0.7440	0.7443	0.7446	0.7448	0.7451	0.7454	0.7459	0.7459
20.....	0.7462	0.7465	0.7468	0.7471	0.7473	0.7476	0.7479	0.7482	0.7485	0.7487
21.....	0.7490	0.7493	0.7496	0.7499	0.7501	0.7504	0.7507	0.7510	0.7513	0.7516
22.....	0.7518	0.7521	0.7524	0.7527	0.7530	0.7533	0.7535	0.7538	0.7541	0.7544
23.....	0.7547	0.7550	0.7552	0.7555	0.7558	0.7561	0.7564	0.7567	0.7570	0.7572
24.....	0.7575	0.7578	0.7581	0.7584	0.7587	0.7590	0.7593	0.7595	0.7598	0.7601
25.....	0.7604	0.7607	0.7610	0.7613	0.7616	0.7619	0.7621	0.7624	0.7627	0.7630
26.....	0.7633	0.7636	0.7639	0.7642	0.7645	0.7648	0.7651	0.7654	0.7656	0.7659
27.....	0.7662	0.7665	0.7668	0.7671	0.7674	0.7677	0.7680	0.7683	0.7686	0.7689
28.....	0.7692	0.7695	0.7698	0.7701	0.7704	0.7707	0.7710	0.7713	0.7716	0.7719
29.....	0.7722	0.7724	0.7727	0.7730	0.7733	0.7736	0.7739	0.7742	0.7745	0.7748
30.....	0.7751	0.7754	0.7757	0.7760	0.7763	0.7766	0.7770	0.7773	0.7776	0.7779
31.....	0.7782	0.7785	0.7788	0.7791	0.7794	0.7797	0.7800	0.7803	0.7806	0.7809
32.....	0.7812	0.7813	0.7818	0.7821	0.7824	0.7827	0.7830	0.7833	0.7836	0.7840
33.....	0.7843	0.7846	0.7849	0.7852	0.7855	0.7858	0.7861	0.7864	0.7867	0.7870

*Part of this Table (15° C.-25° C.) due to Buisson (Bl. Assoc. 20, 275).

TABLE VIII

Table of Factors for Clerget Determination $\frac{(a-b)\ 100}{142.66 - 1/2\ T.}$

(W. G. Taggart.)

Degrees Centigrade	Tenths of a Degree									
	0	1	2	3	4	5	6	7	8	9
15.....	0.7398	0.7401	0.7404	0.7406	0.7409	0.7412	0.7415	0.7417	0.7420	0.7423
16.....	0.7426	0.7429	0.7431	0.7434	0.7437	0.7440	0.7442	0.7445	0.7448	0.7451
17.....	0.7453	0.7456	0.7459	0.7462	0.7464	0.7467	0.7470	0.7473	0.7476	0.7478
18.....	0.7481	0.7483	0.7486	0.7489	0.7492	0.7495	0.7498	0.7500	0.7503	0.7506
19.....	0.7509	0.7511	0.7514	0.7517	0.7520	0.7523	0.7526	0.7529	0.7532	0.7535
20.....	0.7538	0.7540	0.7543	0.7546	0.7549	0.7552	0.7555	0.7558	0.7560	0.7563
21.....	0.7566	0.7569	0.7572	0.7575	0.7578	0.7580	0.7583	0.7586	0.7589	0.7592
22.....	0.7595	0.7598	0.7601	0.7603	0.7606	0.7609	0.7612	0.7615	0.7618	0.7621
23.....	0.7624	0.7627	0.7630	0.7633	0.7635	0.7638	0.7641	0.7644	0.7647	0.7650
24.....	0.7653	0.7656	0.7659	0.7662	0.7665	0.7668	0.7671	0.7674	0.7676	0.7679
25.....	0.7682	0.7685	0.7688	0.7691	0.7694	0.7697	0.7700	0.7703	0.7706	0.7709
26.....	0.7712	0.7715	0.7718	0.7721	0.7724	0.7727	0.7730	0.7733	0.7736	0.7739
27.....	0.7742	0.7745	0.7748	0.7751	0.7754	0.7757	0.7760	0.7763	0.7765	0.7769
28.....	0.7772	0.7775	0.7778	0.7781	0.7784	0.7787	0.7790	0.7793	0.7796	0.7799
29.....	0.7802	0.7805	0.7808	0.7811	0.7814	0.7817	0.7821	0.7824	0.7827	0.7830
30.....	0.7833	0.7836	0.7839	0.7842	0.7845	0.7848	0.7851	0.7854	0.7857	0.7861
31.....	0.7864	0.7867	0.7870	0.7873	0.7876	0.7879	0.7882	0.7885	0.7888	0.7892
32.....	0.7895	0.7898	0.7901	0.7904	0.7907	0.7910	0.7913	0.7916	0.7919	0.7923
33.....	0.7926	0.7929	0.7932	0.7935	0.7938	0.7941	0.7943	0.7946	0.7949	0.7954

PURITY TABLES. (1)

(1) The following tables have been compiled, partly with the aid of Kottman's tables, with the view of facilitating the calculation of sugar house results. (Wm. E. Cross and W. G. Taggart.)

	10 BRIX									
Sucrose	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
5.5	55.0	54.5	53.9	53.4	52.9	52.4	51.9	51.4	50.9	50.5
.6	56.0	55.4	54.9	54.4	53.8	53.3	52.8	52.3	51.8	51.4
.7	57.0	56.4	55.9	55.3	54.8	54.3	53.8	53.3	52.8	52.3
.8	58.0	57.4	56.9	56.3	55.8	55.2	54.7	54.2	53.7	53.2
.9	59.0	58.4	57.8	57.3	56.7	56.2	55.6	55.1	54.6	54.1
6.0	60.0	59.4	58.8	58.3	57.7	57.1	56.6	56.1	55.6	55.0
.1	61.0	60.4	59.8	59.2	58.6	58.1	57.5	57.0	56.5	56.0
.2	62.0	61.4	60.8	60.2	59.6	59.0	58.5	57.9	57.4	56.9
.3	63.0	62.4	61.8	61.2	60.6	60.0	59.4	58.9	58.3	57.8
.4	64.0	63.4	62.7	62.1	61.5	60.9	60.4	59.8	59.3	58.7
.5	65.0	64.4	63.7	63.1	62.5	61.9	61.3	60.7	60.2	59.6
.6	66.0	65.3	64.7	64.1	63.5	62.9	62.3	61.7	61.1	60.6
.7	67.0	66.3	65.7	65.0	64.4	63.8	63.2	62.6	62.0	61.5
.8	68.0	67.3	66.7	66.0	65.4	64.8	64.2	63.5	63.0	62.4
.9	69.0	68.3	67.6	67.0	66.3	65.7	65.1	64.5	63.9	63.3
7.0	70.0	69.3	68.6	68.0	67.3	66.7	66.0	65.4	64.8	64.2
.1	71.0	70.3	69.6	68.9	68.3	67.6	67.0	66.3	65.7	65.1
.2	72.0	71.3	70.6	69.9	69.2	68.6	67.9	67.3	66.7	66.1
.3	73.0	72.3	71.6	70.9	70.2	69.5	68.9	68.2	67.6	67.0
.4	74.0	73.3	72.6	71.8	71.1	70.5	69.8	69.2	68.5	67.9
.5	75.0	74.3	73.5	72.8	72.1	71.4	70.8	70.1	69.4	68.8
.6	76.0	75.2	74.5	73.8	73.1	72.4	71.7	71.0	70.4	69.7
.7	77.0	76.2	75.5	74.7	74.0	73.3	72.6	72.0	71.3	70.6
.8	78.0	77.2	76.5	75.7	75.0	74.3	73.6	72.9	72.2	71.6
.9	79.0	78.2	77.5	76.7	76.0	75.2	74.5	73.8	73.2	72.5
8.0	80.0	79.2	78.4	77.7	76.9	76.2	75.5	74.8	74.1	73.4
.1	81.0	80.2	79.4	78.6	77.9	77.1	76.4	75.7	75.0	74.3
.2	82.0	81.2	80.4	79.6	78.8	78.1	77.4	76.6	75.9	75.2
.3	83.0	82.2	81.4	80.6	79.8	79.0	78.3	77.6	76.8	76.1
.4	84.0	83.2	82.3	81.5	80.8	80.0	79.2	78.5	77.8	77.1
.5	85.0	84.2	83.3	82.5	81.7	80.9	80.2	79.4	78.7	78.0

11 BRIX

Sucrose	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
6.0	54.5	54.1	53.6	53.1	52.6	52.2	51.7	51.3	50.8	50.4
.1	55.5	55.0	54.5	54.0	53.5	53.0	52.6	52.1	51.7	51.3
.2	56.4	55.9	55.4	54.9	54.4	53.9	53.4	53.0	52.5	52.1
.3	57.3	56.8	56.2	55.8	55.3	54.8	54.3	53.8	53.4	52.9
.4	58.2	57.7	57.1	56.6	56.1	55.6	55.2	54.7	54.2	53.8
.5	59.1	58.6	58.0	57.5	57.0	56.5	56.0	55.6	55.1	54.6
.6	60.0	59.5	58.9	58.4	57.9	57.4	56.9	56.4	55.9	55.5
.7	60.9	60.4	59.8	59.3	58.8	58.3	57.8	57.3	56.8	56.3
.8	61.8	61.3	60.7	60.1	59.6	59.1	58.7	58.1	57.6	57.1
.9	62.7	62.2	61.6	61.1	60.5	60.0	59.5	59.0	58.5	58.0
7.0	63.6	63.1	62.5	61.9	61.4	60.9	60.4	59.8	59.3	58.8
.1	64.5	64.0	63.4	62.8	62.3	61.7	61.2	60.7	60.2	59.6
.2	65.5	64.9	64.3	63.7	63.2	62.6	62.1	61.6	61.0	60.5
.3	66.4	65.8	65.2	64.6	64.0	63.5	63.0	62.4	61.8	61.3
.4	67.3	66.7	66.1	65.5	64.9	64.3	63.8	63.2	62.7	62.2
.5	68.2	67.6	66.9	66.4	65.8	65.2	64.7	64.1	63.5	63.0
.6	69.1	68.5	67.9	67.3	66.7	66.1	65.5	65.0	64.4	63.9
.7	70.0	69.4	68.7	68.1	67.5	67.0	66.4	65.8	65.3	64.7
.8	70.9	70.3	69.6	69.0	68.4	67.8	67.2	66.7	66.1	65.5
.9	71.8	71.2	70.5	70.0	69.3	68.7	68.1	67.5	67.0	66.4
8.0	72.7	72.1	71.4	70.8	70.2	69.6	69.0	68.4	67.8	67.2
.1	73.6	73.0	72.3	71.7	71.1	70.4	69.9	69.2	68.6	68.0
.2	74.5	73.9	73.2	72.6	71.9	71.3	70.7	70.1	69.5	68.9
.3	75.5	74.8	74.1	73.5	72.8	72.2	71.6	70.9	70.4	69.7
.4	76.4	75.7	75.0	74.3	73.7	73.0	72.4	71.8	71.2	70.6
.5	77.3	76.6	75.9	75.2	74.6	73.9	73.3	72.7	72.1	71.4
.6	78.2	77.5	76.8	76.1	75.4	74.8	74.1	73.5	72.9	72.3
.7	79.1	78.4	77.7	77.0	76.3	75.7	75.0	74.4	73.7	73.1
.8	80.0	79.3	78.6	77.9	77.2	76.5	75.9	75.2	74.6	73.9
.9	80.9	80.2	79.5	78.8	78.1	77.4	76.7	76.1	75.4	74.8
9.0	81.8	81.1	80.4	79.6	78.9	78.3	77.6	76.9	76.3	75.6
.1				80.5	79.8	89.2	78.4	77.8	77.1	76.5
.2				81.4	80.7	80.0	79.3	78.6	77.9	77.3
.3					81.6	80.8	80.2	79.5	78.8	78.1
.4					82.5	81.7	81.0	80.3	79.7	79.0
.5						82.6	81.9	81.2	80.5	79.8
.6						83.5	82.8	82.1	81.4	80.7
.7							83.6	82.9	82.2	81.5
.8							84.5	83.8	83.1	82.4
.9									83.9	83.2

Sucrose	12 BRIX									
	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
7.0	58.3	57.9	57.4	56.9	56.5	56.0	55.6	55.1	54.7	54.3
.1	59.2	58.7	58.2	57.7	57.3	56.8	56.3	55.9	55.5	55.0
.2	60.0	59.5	59.0	58.5	58.1	57.6	57.1	56.7	56.2	55.8
.3	60.8	60.3	59.9	59.4	58.9	58.4	57.9	57.5	57.0	56.6
.4	61.6	61.2	60.7	60.2	59.6	59.2	58.7	58.3	57.8	57.4
.5	62.5	62.0	61.5	61.0	60.5	60.0	59.5	59.1	58.6	58.1
.6	63.3	62.8	62.3	61.8	61.3	60.8	60.3	59.8	59.4	58.9
.7	64.2	63.6	63.1	62.6	62.1	61.6	61.1	60.6	60.1	59.7
.8	65.0	64.5	64.0	63.4	62.9	62.4	61.9	61.4	60.9	60.5
.9	65.8	65.3	64.8	64.2	63.7	63.2	62.7	62.2	61.7	61.2
8.0	66.7	66.1	65.6	65.0	64.5	64.0	63.5	63.0	62.5	62.0
.1	67.5	66.9	66.4	65.9	65.3	64.8	64.3	63.8	63.3	62.8
.2	68.3	67.8	67.2	66.7	66.1	65.6	65.1	64.6	64.1	63.6
.3	69.2	68.6	68.0	67.5	66.9	66.4	65.9	65.4	64.8	64.3
.4	70.0	69.4	68.8	68.3	67.7	67.2	66.7	66.1	65.6	65.1
.5	70.8	70.2	69.7	69.1	68.5	68.0	67.5	66.9	66.4	65.9
.6	71.7	71.1	70.5	69.9	69.3	68.8	68.3	67.7	67.2	66.7
.7	72.5	71.9	71.3	70.7	70.1	69.6	69.0	68.5	67.9	67.4
.8	73.3	72.7	72.1	71.5	71.0	70.4	69.8	69.3	68.8	68.2
.9	74.2	73.6	73.0	72.4	71.8	71.2	70.6	70.1	69.5	69.0
9.0	75.0	74.4	73.8	73.2	72.6	72.0	71.4	70.9	70.3	69.8
.1	75.8	75.2	74.6	74.0	73.4	72.8	72.2	71.7	71.1	70.5
.2	76.7	76.0	75.4	74.8	74.2	73.6	73.0	72.4	71.9	71.3
.3	77.5	76.8	76.2	75.6	75.0	74.4	73.8	73.2	72.6	72.1
.4	78.3	77.7	77.0	76.4	75.8	75.2	74.6	74.0	73.4	72.9
.5	79.2	78.5	77.8	77.2	76.6	76.0	75.4	74.8	74.2	73.6
.6	80.0	79.3	78.7	78.0	77.4	76.8	76.2	75.6	75.0	74.4
.7	80.8	80.2	79.5	78.9	78.2	77.6	77.0	76.4	75.8	75.2
.8	81.7	81.0	80.3	79.7	79.0	78.4	77.8	77.2	76.6	76.0
.9	82.5	81.8	81.2	80.5	79.8	79.2	78.6	78.0	77.4	76.7
10.0	83.3	82.6	82.0	81.3	80.6	80.0	79.4	78.7	78.1	77.5
.1			82.8	82.1	81.4	80.8	80.2	79.5	78.9	78.3
.2			83.6	82.9	82.3	81.6	81.0	80.3	79.7	79.1
.3				83.8	83.0	82.4	81.7	81.1	80.5	79.9
.4				84.6	83.9	83.2	82.5	81.9	81.2	80.6
.5					84.7	84.0	83.3	82.7	82.0	81.4
.6					85.5	84.8	84.1	83.5	82.8	82.2
.7								84.3	83.6	83.0
.8								85.0	84.4	83.7
.9										84.5
11.0										85.3

PURITY TABLES.

13 BRIX

Sucrose	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
8.5	65.4	64.9	64.4	63.9	63.4	63.0	62.5	62.0	61.6	61.1
.6	66.2	65.6	65.2	64.7	64.2	63.7	63.2	62.8	62.3	61.9
.7	66.9	66.4	65.9	65.4	64.9	64.4	64.0	63.5	63.0	62.6
.8	67.7	67.2	66.7	66.2	65.7	65.2	64.7	64.2	63.8	63.3
.9	68.5	67.9	67.4	66.9	66.4	65.9	65.4	65.0	64.5	64.0
9.0	69.2	68.7	68.2	67.7	67.2	66.7	66.2	65.7	65.2	64.7
.1	70.0	69.5	68.9	68.4	67.9	67.4	66.9	66.4	65.9	65.5
.2	70.8	70.2	69.7	69.2	68.7	68.1	67.6	67.2	66.7	66.2
.3	71.5	71.0	70.5	69.9	69.4	68.9	68.4	67.9	67.4	66.9
.4	72.3	71.8	71.2	70.7	70.1	69.6	69.1	68.6	68.1	67.6
.5	73.1	72.5	72.0	71.4	70.9	70.4	69.8	69.3	68.8	68.3
.6	73.8	73.3	72.7	72.2	71.6	71.1	70.6	70.1	69.6	69.1
.7	74.6	74.0	73.5	72.9	72.4	71.9	71.3	70.8	70.3	69.8
.8	75.4	74.8	74.2	73.7	73.1	72.6	72.1	71.5	71.0	70.5
.9	76.2	75.6	75.0	74.4	73.9	73.3	72.8	72.3	71.7	71.2
10.0	76.9	76.3	75.8	75.2	74.6	74.1	73.5	73.0	72.5	71.9
.1	77.7	77.1	76.5	75.9	75.4	74.8	74.3	73.7	73.2	72.7
.2	78.5	77.9	77.3	76.7	76.1	75.6	75.0	74.5	73.9	73.4
.3	79.2	78.6	78.0	77.4	76.9	76.3	75.7	75.2	74.6	74.1
.4	80.0	79.4	78.8	78.2	77.6	77.0	76.5	75.9	75.4	74.8
.5	80.8	80.2	79.5	78.9	78.4	77.8	77.2	76.6	76.1	75.5
.6	81.5	80.9	80.3	79.7	79.1	78.5	77.9	77.4	76.8	76.3
.7	82.3	81.7	81.1	80.5	79.9	79.3	78.7	78.1	77.5	77.0
.8	83.1	82.4	81.8	81.2	80.6	80.0	79.4	78.8	78.3	77.7
.9	83.8	83.2	82.6	82.0	81.3	80.7	80.1	79.6	79.0	78.4
11.0	84.6	84.0	83.3	82.7	82.1	81.5	80.9	80.3	79.7	79.1
.1	85.4	84.7	84.1	83.5	82.8	82.2	81.5	81.0	80.4	79.9
.2	86.2	85.5	84.8	84.2	83.6	83.0	82.4	81.8	81.2	80.6
.3	86.9	86.3	85.6	85.0	84.3	83.7	83.1	82.5	81.9	81.3
.4	87.7	87.0	86.4	85.7	85.1	84.4	83.8	83.2	82.6	82.0
.5				86.5	85.8	85.2	84.6	83.9	83.3	82.7
.6				87.2	86.6	85.9	85.3	84.7	84.1	83.5
.7								85.4	84.8	84.2
.8								86.1	85.5	84.9
.9										85.6

	14 BRIX									
Sucrose	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
9.0	64.3	63.8	63.4	62.9	62.5	62.1	61.6	61.2	60.8	60.4
.1	65.0	64.5	64.1	63.6	63.2	62.8	62.3	61.9	61.5	61.1
.2	65.7	65.2	64.8	64.3	63.9	63.4	63.0	62.6	62.2	61.7
.3	66.4	66.0	65.5	65.0	64.6	64.1	63.7	63.3	62.8	62.4
.4	67.1	66.7	66.2	65.7	63.3	64.8	64.4	64.0	63.5	63.1
.5	67.9	67.4	66.9	66.4	66.0	65.5	65.1	64.6	64.2	63.8
.6	68.6	68.1	67.6	67.1	66.7	66.2	65.8	65.3	64.9	64.4
.7	69.3	68.8	68.3	67.8	67.4	66.9	66.4	66.0	65.5	65.1
.8	70.0	69.5	69.0	68.5	68.1	67.6	67.1	66.7	66.2	65.8
.9	70.7	70.2	69.7	69.2	68.7	68.3	67.8	67.4	66.9	66.4
10.0	71.4	70.9	70.4	69.9	69.4	69.0	68.5	68.0	67.6	67.1
.1	72.1	71.6	71.1	70.6	70.1	69.7	69.2	68.7	68.2	67.8
.2	72.9	72.3	71.8	71.3	70.8	70.3	69.9	69.4	68.9	68.5
.3	73.6	73.0	72.5	72.0	71.5	71.0	70.5	70.0	69.6	69.1
.4	74.3	73.8	73.2	72.7	72.2	71.7	71.2	70.7	70.3	69.8
.5	75.0	74.5	73.9	73.4	72.9	72.4	71.9	71.4	70.9	70.5
.6	75.7	75.2	74.6	74.1	73.6	73.1	72.6	72.1	71.6	71.1
.7	76.4	75.9	75.4	74.8	74.3	73.8	73.3	72.8	72.3	71.8
.8	77.1	76.6	76.1	75.5	75.0	74.5	74.0	73.5	73.0	72.5
.9	77.9	77.3	76.8	76.2	75.7	75.2	74.7	74.1	73.6	73.2
11.0	78.6	78.0	77.5	76.9	76.4	75.9	75.3	74.8	74.3	73.8
.1	79.3	78.7	78.2	77.6	77.1	76.6	76.0	75.5	75.0	74.5
.2	80.0	79.4	78.9	78.3	77.8	77.2	76.7	76.2	75.7	75.2
.3	80.7	80.1	79.6	79.0	78.5	77.9	77.4	76.9	76.4	75.9
.4	81.4	80.9	80.3	79.7	79.2	78.6	78.1	77.6	77.0	76.5
.5	82.1	81.6	81.0	80.4	79.9	79.3	78.8	78.2	77.7	77.2
.6	82.9	82.3	81.7	81.1	80.6	80.0	79.4	78.9	78.4	77.9
.7	83.6	83.0	82.4	81.8	81.2	80.7	80.1	79.6	79.1	78.5
.8	84.3	83.7	83.1	82.5	81.9	81.4	80.8	80.3	79.7	79.2
.9	85.0	84.4	83.8	83.2	82.6	82.1	81.5	81.0	80.4	79.9
12.0	85.7	85.1	84.5	83.9	83.3	82.8	82.2	81.6	81.1	80.5
.1			85.2	84.6	84.0	83.4	82.9	82.3	81.8	81.2
.2			85.9	85.3	84.7	84.1	83.6	83.0	82.4	81.9

Sucrose	15 BRIX									
	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
10.0	66.7	66.2	65.8	65.4	64.9	64.5	64.1	63.7	63.3	62.9
.1	67.3	66.9	66.4	66.0	65.6	65.2	64.7	64.3	63.9	63.5
.2	68.0	67.5	67.1	66.7	66.2	65.8	65.3	64.9	64.6	64.1
.3	68.7	68.2	67.7	67.3	66.9	66.5	66.0	65.6	65.2	64.8
.4	69.3	68.9	68.0	67.9	67.5	67.1	66.7	66.2	65.8	65.3
.5	70.0	69.5	69.0	68.6	68.1	67.7	67.3	66.9	66.5	66.0
.6	70.7	70.2	69.7	69.3	68.8	68.4	67.9	67.5	67.1	66.7
.7	71.3	70.9	70.4	69.9	69.5	69.0	68.6	68.2	67.7	67.3
.8	72.0	71.5	71.1	70.6	70.1	69.7	69.2	68.8	68.4	67.9
.9	72.7	72.2	71.7	71.2	70.8	70.3	69.9	69.4	69.0	68.6
11.0	73.3	72.8	72.4	71.9	71.4	71.0	70.5	70.0	69.6	69.1
.1	74.0	73.5	73.0	72.5	72.1	71.6	71.2	70.8	70.2	69.8
.2	74.7	74.2	73.7	73.2	72.7	72.3	71.8	71.3	70.9	70.4
.3	75.3	74.8	74.3	73.8	73.4	72.9	72.3	71.9	72.5	71.0
.4	76.0	75.5	75.0	74.5	74.0	73.5	73.1	72.6	72.2	71.7
.5	76.7	76.2	75.7	75.2	74.7	74.2	73.7	73.3	72.7	72.3
.6	77.3	76.8	76.3	75.8	75.3	74.8	74.4	73.9	73.4	73.0
.7	78.0	77.5	77.0	76.5	76.0	75.5	75.0	74.5	74.0	73.6
.8	78.7	78.1	77.6	77.1	76.6	76.1	75.6	75.2	74.7	74.2
.9	79.3	78.8	78.3	77.8	77.3	76.8	76.3	75.8	75.3	74.8
12.0	80.0	79.5	78.9	78.4	77.9	77.4	76.9	76.4	75.9	75.5
.1	80.7	80.1	79.6	79.1	78.6	78.1	77.6	77.1	76.6	76.1
.2	81.3	80.8	80.3	79.7	79.2	78.7	78.2	77.7	77.2	76.7
.3	82.0	81.5	80.9	80.4	79.9	79.4	78.9	78.3	77.8	77.4
.4	82.7	82.1	81.6	81.0	80.5	80.0	79.5	79.0	78.5	78.0
.5	83.3	82.8	82.3	81.7	81.2	80.7	80.1	79.6	79.1	78.6
.6	84.0	83.4	82.9	82.4	81.8	81.3	80.8	80.3	79.7	79.2
.7	84.7	84.1	83.6	83.0	82.5	81.9	81.4	80.9	80.4	79.9
.8	85.3	84.8	84.2	83.7	83.1	82.6	82.1	81.5	81.0	80.5
.9	86.0	85.4	84.9	84.3	83.8	83.2	82.7	82.2	81.6	81.1
13.0	86.7	86.1	85.5	85.0	84.4	83.9	83.3	82.8	82.3	81.8
.1	87.3	86.8	86.2	85.6	85.1	84.5	84.0	83.4	82.9	82.4
.2	88.0	87.4	86.8	86.3	85.7	85.2	84.6	84.1	83.5	83.0